Guidance for interpretation of CBD categories on introduction pathways

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Rationale

Biological invasions are widely recognised as a major driver of global biodiversity loss (CBD 2006) and have the potential to cause significant socio-economic impact. The first stage of the invasion process is the human-assisted movement of living organisms or propagules beyond their native range (Blackburn et al. 2011) involving a number of pathways and vectors. The increase in globalisation, and associated increase in transport, trade, travel and tourism, are considered key factors in the movement of species around the globe at an increasing rate (Hulme 2009, Butchart et al. 2010, Essl et al. 2015). These activities provide vectors and pathways for live plants, animals and biological material to cross those biogeographical barriers that would usually block their movement and spread. Once transported to a new region, alien, and potentially invasive, species can subsequently move, or be transported, from that region to other new regions. Understanding the importance of specific alien species' pathways is seen as critical for managing the threat posed by alien species (EC 2011, CBD 2014a).

Pyšek et al. (2011) defined pathways as "*a suite of processes that result in the introduction of an alien species from one geographical location to another", and vectors as "dispersal mechanisms and means of introduction*". Such definitions concur with Genovesi and Shine (2004), according to whom "pathway" means, as applicable:

- geographic route by which a species is moved outside its natural range (past or present);
- corridor of introduction (e.g. road, canal, tunnel); and/or
- human activity that gives rise to an intentional or unintentional introduction.

Similarly the term "vector" means the physical means or agent (i.e. aeroplane, ship) in or on which a species moves outside its native range (past or present).

The European Union (EU), with the aim to protect biodiversity and ecosystem services, as well as to minimize and mitigate the impacts that invasive alien species (IAS) can have on human health and other socio-economic sectors, has adopted Regulation (EU) no. 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of IAS (herein referred to as "EU Regulation on IAS") which entered into force in 2015 (European Union 2014). This Regulation seeks to address the problem of IAS in a comprehensive manner. The core of the system is an open "list of IAS of Union concern" for which a general ban from the EU, including introduction, transport, trade, keeping, breeding and release into the environment, is established (but the Regulation also provides for a system of authorizations and permits to allow certain activities based on IAS). The list, which is to be kept regularly updated and reviewed at least every six years, is based on risk assessments which satisfy certain conditions or minimum standards (e.g. see also Roy et al. 2014, Roy et al. 2017a), which includes documenting information on current and potential pathways.

The EU Regulation on IAS also includes other innovative pathway-related measures, such as the provisions of art. 13, according to which "*Member States shall, within 18 months of the adoption of the Union list carry out a comprehensive analysis of the pathways of*

unintentional introduction and spread of invasive alien species of Union concern" and "*Within three years of the adoption of the Union list, each Member State shall establish and implement one single action plan or a set of action plans to address the priority pathways*" (see Scalera and Genovesi 2016). Therefore, whether a specific pathway can be tackled by an action plan depends on the condition that at least one representative species is included on the EU list (Carboneras et al. 2017). Additionally, it is clear that precise, reliable and detailed information on pathways is key for the development of alien species risk assessments, management (specifically prevention strategies), monitoring, and surveillance (Essl et al. 2015). Essl et al. (2015) further highlights the need to "apply consistent pathway classification, hierarchy, and terminology". A common terminology is crucial to facilitate data exchange across countries, years, and/or databases ultimately enabling comparative analysis of trends (CBD 2014a). Furthermore, it could facilitate the assessment of the risks posed by pathways, and to identify the best management responses (Scalera et al. 2016).

A standardized pathway terminology and classification was first proposed (Hulme et al. 2008) and modified through collaborative work, resulting in a unified system to categorise introduction pathways of IAS as proposed in the document of the Convention on Biological Diversity (CBD) on "Pathways of introduction of invasive species, their prioritization and management" (CBD 2014a, herein referred to as **CBD pathways categorisation**). In short, the CBD pathways categorization distinguishes intentional and/or unintentional introductions, and the introduction mechanism as either the importation of a commodity, arrival via a transport vector, the establishment of an anthropogenic dispersal corridor, or the natural spread from a region where the species is itself alien (see **Table 1** below). These mechanisms are divided into six main groups: Release; Escape; Transport - contaminants; Transport - stowaway; Corridors; and Unaided (**Figure 1**). As the level of detail required in pathway classification depends on the management goal (see Essl et al. 2015), a number of subcategories are also proposed.

Table 1 The CBD pathways categorisation for the introduction of alien species (from UNEP/CBD/SBSTTA/18/9/Add.1)

	Category	Subcategory
Movement of COMMODITY	**RELEASE** IN NATURE	Biological control Erosion control/ dune stabilization (windbreaks, hedges, …) Fishery in the wild (including game fishing) Hunting Landscape/flora/fauna "improvement" in the wild Introduction for conservation purposes or wildlife management Release in nature for use (other than above, e.g., fur, transport, medical use) Other intentional release
	ESCAPE FROM CONFINEMENT	Agriculture (including Biofuel feedstocks) Aquaculture / mariculture Botanical garden/zoo/aquaria (excluding domestic aquaria) Pet/aquarium/terrarium species (including live food for such species) Farmed animals (including animals left under limited control) Forestry (including reforestation) Fur farms Horticulture Ornamental purpose other than horticulture Research and ex-situ breeding (in facilities) Live food and live bait Other escape from confinement
	TRANSPORT – **CONTAMINANT**	Contaminant nursery material Contaminated bait Food contaminant (including of live food) Contaminant on animals (except parasites, species transported by host/vector) Parasites on animals (including species transported by host and vector) Contaminant on plants (except parasites, species transported by host/vector) Parasites on plants (including species transported by host and vector) Seed contaminant Timber trade Transportation of habitat material (soil, vegetation,…)
VECTOR	TRANSPORT - **STOWAWAY**	Angling/fishing equipment Container/bulk Hitchhikers in or on airplane Hitchhikers on ship/boat (excluding ballast water and hull fouling) Machinery/equipment People and their luggage/equipment (in particular tourism) Organic packing material, in particular wood packaging Ship/boat ballast water Ship/boat hull fouling Vehicles (car, train, …) Other means of transport
SPREAD	**CORRIDOR**	Interconnected waterways/basins/seas Tunnels and land bridges
	UNAIDED	Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5

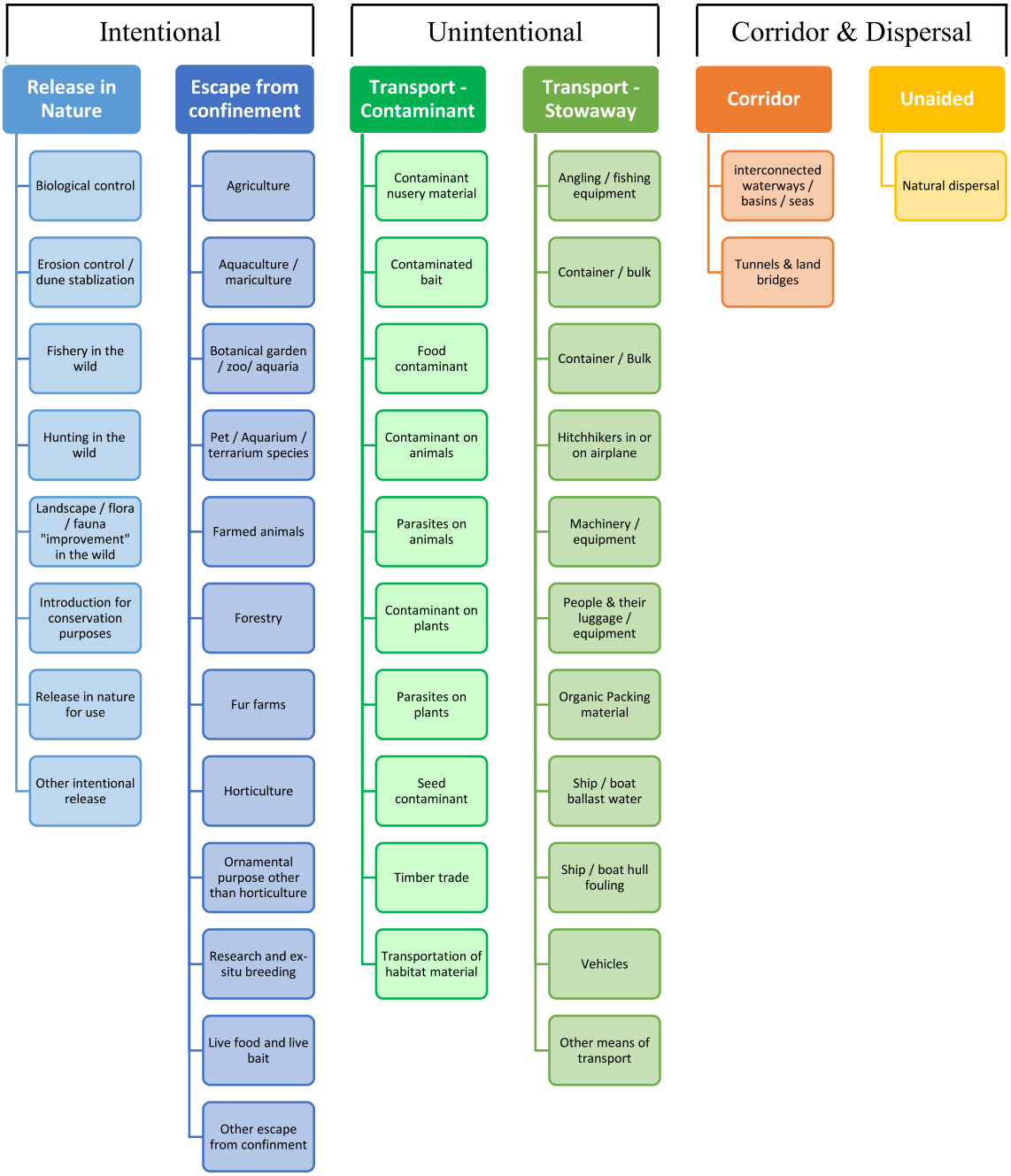


Figure 1 An overview of the CBD pathways categorisation scheme showing how the 44 pathway subcategories relate to the six main pathway categories. All of the pathways in this classification can be broadly classified into three types; 1) those that involve intentional transport of taxa (blue) 2) those in which the taxa was unintentionally transported (green), and 3) those where the taxa moved between regions without direct transportation by humans and/or via artificial corridors (orange & yellow).

The aim of adopting a shared terminology, ideally at the global scale, is based on the policy framework according to which CBD Parties and other Governments are required to consider (see CBD 2014b) "*Identifying and prioritizing pathways of introduction of invasive alien species, taking into account, inter alia, information on the taxa, the frequency of introduction, and the magnitude of impacts, as well as climate change scenarios*" (i.e. "*when developing or updating and implementing their national or regional invasive alien species strategies, to consider, on a voluntary basis and in conjunction with the items listed in decision VI/23*").

This is compliant with the Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets "Living in Harmony with Nature" (CBD 2010). Specifically, according to Aichi Biodiversity Target 9 "*By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment*". In this context, the EU Regulation on IAS is the most comprehensive European policy measure to date towards meeting CBD Aichi Biodiversity Target 9 and the EU Biodiversity Strategy Target 5, according to which "*By 2020, IAS and their pathways are identified and prioritised, priority species are controlled or eradicated and pathways are managed to prevent the introduction and establishment of new IAS*" (EC 2011).

Lessons learned and challenges of developing and applying the categorisation system to existing datasets

The CBD pathways categorisation (CBD 2014a) discussed in this document was developed by the Invasive Species Specialist Group of IUCN's Species Survival Commission (IUCN SSC-ISSG), in collaboration with the Centre for Ecology and Hydrology (CEH, UK), CAB International (CABI) and other partners, within the framework of the CBD related Global Invasive Alien Species Information Partnership (GIASIP), and is based upon a system proposed by Hulme (2009). It was aimed to provide countries with tools for the categorisation and ultimately prioritization of IAS pathways.

The CBD pathways categorisation has been tested using major global (IUCN SSC-ISSG Global Invasive Species Database, GISD), regional (Europe: Delivering Alien Invasive Species Inventories for Europe, DAISIE) and national (Great Britain: Great Britain's Non-Native Species Information Portal, GBNNSIP) databases. The testing phase occurred prior to the publication of the categorisation scheme in the CBD note (CBD 2014a), and was carried out on an earlier version of the scheme which, following the revisions based on these investigations (particularly the comparisons with GISD, DAISIE, and GBNNSIP), led to the final version outlined in the CBD note (CBD 2014a). The Invasive Species Compendium (ISC) of CABI, DAISIE and some key peer-reviewed literature were also used.

Initial testing of the categorisation scheme involved comparison with the different classification schemes used in these large alien species databases to determine what proportion of the pathway categories had equivalents in the proposed categorisation scheme and to ensure that all important pathways were covered. It was found that a notable proportion of the pathways in the existing classification schemes had equivalent pathways in the new proposed scheme (Essl *et al.* 2015, Saul *et al.* 2017, Pergl *et al.* 2017, Tsiamis *et al.*

2017), however this proportion varied between databases. In DAISIE 81% of pathway assignments (23,398 entries) in the database were to pathways that had a direct match in the new classification scheme (Natural Environment Research Council 2013) with a similar figure being found for the GBNNSIP, while in the European Alien Species Information Network (EASIN) database the correspondence was notably lower at about 49% (Tsiamis *et al.* 2017).

In situations where the new pathway category completely matches or entirely encompasses previous categories, reclassification or aligning these to the new categorisation scheme is straightforward. The existing pathways for the taxa affected can simply be converted or linked to the new pathways without requiring any re-evaluation of information. It is not so straightforward for pathways which do not align to a single pathway in the proposed scheme, as these require additional work to reclassify or align to the proposed scheme. Some examples of pathways categories from these databases (mentioned above) that were found to align with multiple pathways in the proposed scheme were:

- Leisure pathway in DAISIE – this pathway could encompass several proposed pathways such as **Fishery in the wild**, **Release in nature for use**, **Other intentional release**, **Pet / aquarium / terrarium species**, **Ornamental purpose other than horticulture**, **People and their Luggage/equipment**.
- Vessels pathway in DAISE – this pathway could potentially align to the majority of the proposed pathways within the Transport – Stowaway category, such as **Ship/boat ballast Water**, **Hitchhikers in/on airplane**, **Hitchhikers on ship/boat**, **Ship/boat hull fouling**, or **Vehicles**.
- Contaminated commodities pathway in EASIN – this pathway could potentially align to any of the pathways in the proposed scheme that relate to the production of commercial commodities, such as **Agriculture**, **Forestry**, **Horticulture**, or **Aquaculture / mariculture** pathways.

In some situations it was determined that it may be possible to reclassify or align pathways that overlapped with more than one pathway in the proposed scheme at a group level by utilising broad traits of the taxa and/or the environment in which they occur. For example, the Game Animals pathway in the EASIN classification scheme could map to either the **Hunting** or **Fishing in the wild** pathways in the proposed scheme but the pathways could be reclassified at a group level by assigning all terrestrial taxa to **Hunting** and all aquatic taxa to **Fishing in the wild** (Tsiamis *et al.* 2017). In the majority of cases, however, reclassification or alignment would require revaluation of the pathways on a species by species basis in order to allocate the correct pathway.

From these initial investigations using the initial draft CBD pathways categorisation it was apparent that there were also a small number of cases where pathways in the database investigated had no obvious equivalent in the new scheme. Typically these pathways were marginal ones in the databases only being applied to a limited number of species (or in a couple of instances having never been applied to any species). These non-matched pathways and the taxa they contained were examined to determine if they represented an important introduction pathway that had been overlooked or if they could be aligned to pathways in the new scheme when the specifics of the case were reviewed. Where it was decided that the

non-matched pathways did describe a pathway that had been overlooked, the pathway categories in the new scheme were modified, extended or in limited cases new pathway categories added to develop the **CBD categorisation scheme**. An example of a pathway that was added after the comparisons with existing schemes was the **Natural dispersal** pathway. It was decided that including the ability to categorise situations where alien species first arrive in a region via natural dispersal from another region in which it is also alien e.g. arrival into Europe via natural dispersal from bordering countries, is important and warranted its inclusion in the CBD pathways categorisation.

Saul *et al.* (2017) provides a visual representation of the alignment between the CBD pathways categorisation and the pathway categorisation schemes used by the DAISIE and GISD databases (**Figure 2**, reproduced from Saul *et al.*, 2017). The diagram highlights the points raised above, specifically that the majority of categories in DAISIE and GISD directly correspond to single CBD pathways, that there are some pathways that could align with multiple CBD pathways, and that there are a few pathways that did not appear to align with those in the CBD pathways categorisation (e.g. Hybrid used in DAISIE).

A detailed analysis of the CBD pathway categories was provided for the first time by Saul et al. (2017), who based their work on the pathway information from two of the main global datasets: GISD (updated version www.iucngisd.org) and DAISIE (www.europe-aliens.org). The combined dataset, including both the GISD and DAISIE, included pathway information for 8,323 species across all environments and taxonomic groups (except for micro-organisms). Therefore, it provided an opportunity to test the CBD pathways categorisation using a diverse and large dataset. It was noted that while the combined dataset was useful for assessing global trends, there can be regional idiosyncrasies that support the use of datasets at appropriate scales. The CBD pathways categorisation has also been used effectively for a study using European datasets, DAISIE supplemented by EASIN (Pergl et al. 2017). Both the studies demonstrated that alien species arriving through multiple pathways of introduction were more likely to have negative ecological impacts compared to those arriving by single pathways (Saul et al. 2017, Pergl et al. 2017) perhaps reflecting the high propagule pressure.

As mentioned above, based on these comparisons with existing classification schemes, the earlier draft of the pathway categorisation system was revised to produce the scheme that was proposed by the CBD (CBD 2014a). A key point noted during the investigations and comparisons was that some of the proposed pathway categories were difficult to distinguish, as they appeared to cover other similar pathways, and/or possibly even to overlap with each other. It was therefore suggested that it would be beneficial to have descriptions of the categories in addition to the pathway category titles themselves.

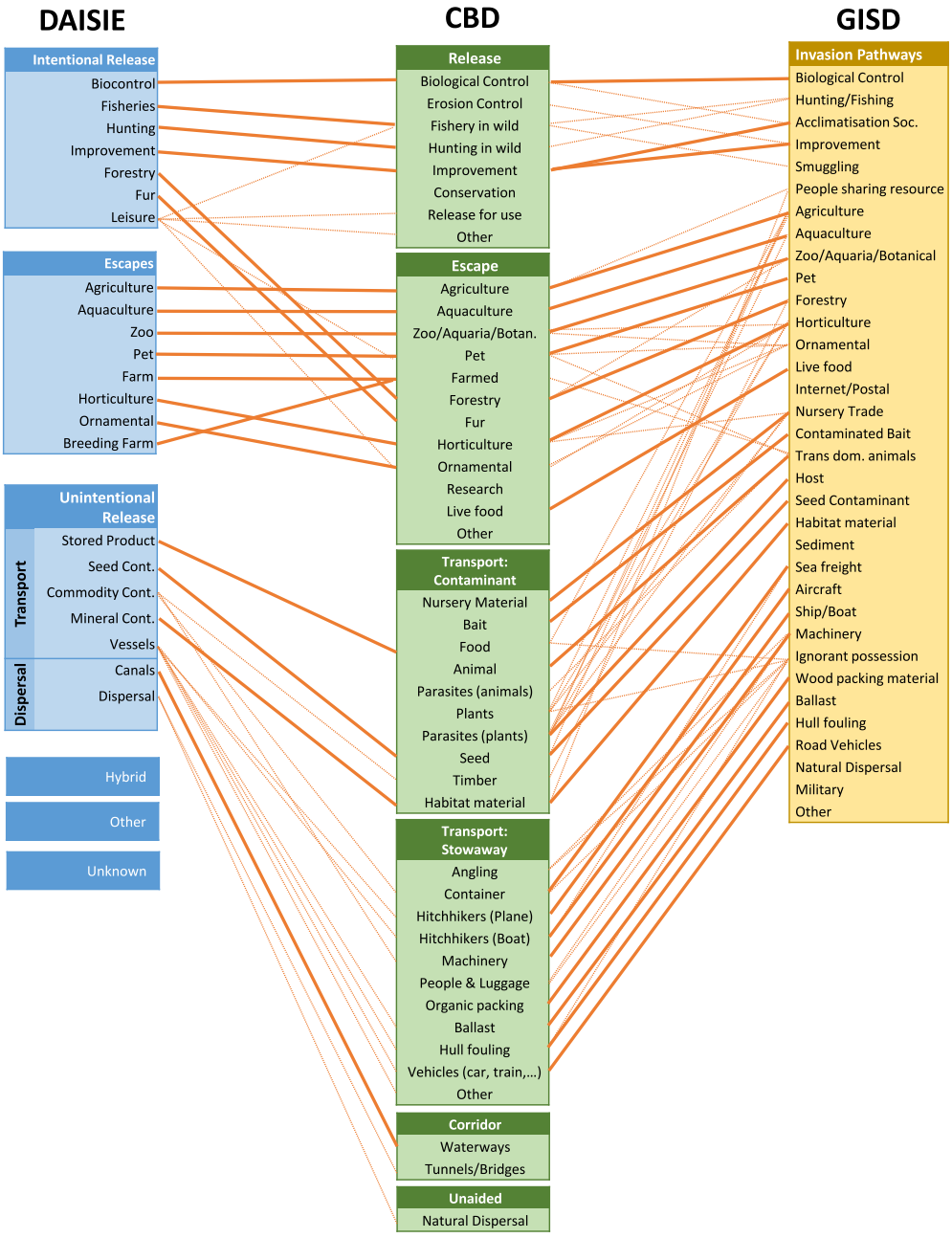


Figure 2 The schematic provides a visual representation of alignment between pathway terminologies used in DAISIE & GISD databases against the CBD pathway categorisation scheme. Solid thick lines represent DAISIE/GISD pathways that correspond to a single CBD pathway while the thin dotted lines represent DAISIE or GISD pathways that could align to multiple CBD pathways. From Saul, W.-C., Roy, H.E., Booy, O., Carnevali, L., Chen, H.-J., Genovesi, P., Harrower, C.A., Hulme, P.E., Pagad, S., Pergl, J. & Jeschke, J.M. (2016) Assessing patterns in introduction pathways of alien species by linking major invasion databases. Journal of Applied Ecology, 54, 657–669 (Figure 1, p660 therein).

Aligning pathways of the EASIN catalogue to the CBD system

The first broad scale initiative to adopt the assignment of pathways of introduction for each species according to the CBD pathways categorisation was launched by the European Commission in relation to EASIN, a platform developed by the Joint Research Centre (JRC) which enables easy access to data on alien species reported in Europe. EASIN builds on collaboration with existing European and global projects to deliver tools and information in support of alien species policies, and is formally recognised as the information exchange mechanism supporting the implementation of EU Regulation on IAS on prevention and management of introduction and spread of IAS (Tsiamis *et al.* 2017).

This realignment of the pathway information in the EASIN catalogue was a multiphase process:

> Phase 1- Identification of pathway categories in the EASIN categorisation scheme that had a direct analogues in the CBD scheme. The taxa assigned to these pathways can be directly mapped to the corresponding analogues in the CBD scheme.
>
> Phase 2 - EASIN categories that could align with multiple pathways were reviewed to determine which could be split between the CBD pathways at the group level based on simple traits of species or their environments (e.g. see example with respect to game animals described above). The taxa in these categories can then be aligned to the relevant CBD pathways based on these traits
>
> Phase 3 - Detailed assessment of the remaining taxa and their introduction pathways on an individual basis using the scientific literature and other relevant sources in order to assign them to the relevant CBD pathways.

Phase 1 and 2 of this process were carried out by the JRC team who host EASIN and are described in a paper by Tsiamis *et al.* (2017), who also provide a full breakdown of the mapping between the old EASIN-categorisation and the CBD categories (**Table 2** and **Figure 3**). Phase 3 was conducted as part of a European Commission funded project (EASIN ENV.B.2/SER/2015/0037rl[1]) and involved a team of experts reviewing the literature for any taxa with pathway information in EASIN that had not been aligned to CBD pathways during Phases 1 or 2. The list for this third phase contained just over 4,000 taxa across a wide range of species.

During the reclassification work it became clear that the CBD pathway definitions could benefit from further modification and refinement, as there were still areas of confusion or uncertainty. Some of this confusion was due to the fact that the definitions did not sufficiently distinguish between similar or overlapping categories to ensure consistent application of the pathway terminology. An example of this is the **Contaminant on plants** pathway, which appeared to overlap with, or contain within it, the **Contaminant nursery material** and, to a lesser degree, the **Transportation of habitat material** pathways. A similar situation was

[1] As a remark, the authors of this note were directly involved in the above mentioned project, hence the discussion below summarises the main points that emerged from the experience, and which are not yet published in any written report.

noted with the **Horticulture, Agriculture, Forestry** and **Ornamental** pathways in that horticulture seems to overlap with, or contain within it, the **Agriculture, Forestry and Ornamental** pathways. It was suggested that a simple way to deal with these overlaps would be to define the pathways relative to other pathways and to deal with them in a set order of precedence, e.g. the **Contaminant on plants** pathway could be defined to contain all contaminants of plants that are not part of nursery trade (where **contaminated nursery material** is given precedence over the **contaminant on plants** pathway).

Table 2 Comparison of sub-category pathways between CBD and EASIN classification systems; pathways in bold font corresponds to perfect match between the two systems; pathways in normal font where an EASIN pathway corresponds to two (or more) CBD pathways (or vice versa in the case of Lessepsian migrants and inland canals); italic font where an EASIN pathway does not match with any CBD pathway or vice versa. The number of related species for each pathway in EASIN is also provided. Table reproduced with altered formatting from Tsiamis, K., Cardoso, A.C. and Gervasini, E. 2017. The European Alien Species Information Network on the Convention on Biological Diversity pathways categorization. *NeoBiota* 32, 21–29. (Table 1, pp23-24 therein).

Category pathways	**CBD sub-category pathways**	**EASIN sub-category**	**EASIN No. of**
Release in nature	**Biological control**	**Biocontrol**	**181**
	Erosion control/ dune stabilization (windbreaks, hedges, …)	Landscaping-Erosion control	64
	Landscape/flora/fauna "improvement" in the wild		
	Fishery in the wild (including game fishing)	Game animals	93
	Hunting		
	Introduction for conservation purposes or wildlife management		
	Release in nature for use (other than above, e.g., fur, transport, medical use)		
	Other intentional release	**Other + Pets, Terrarium-Aquarium species**	**1102**
Escape from confinement	Agriculture (including Biofuel feedstocks)	Cultivation and Livestock	780
	Farmed animals (including animals left under limited control)		
	Forestry (including afforestation or reforestation)		
	Fur farms		
	Horticulture		
	Aquaculture / mariculture	**Aquaculture**	**171**

	Botanical garden/zoo/aquaria (excluding domestic aquaria)	**Zoos, botanical gardens**	**262**
	Pet/aquarium/terrarium species (including live food for such species)	**Pets, Terrarium-Aquarium species**	**246**
	Ornamental purpose other than horticulture	**Ornamental**	**1935**
	Research and ex-situ breeding (in facilities)		
	Live food and live bait	**Use of live food-bait**	**28**
	Other escape from confinement		
Transport – contaminant	Contaminant nursery material	Trade of contaminated commodities	3382
	Contaminated bait		
	Food contaminant (including of live food)		
	Contaminant on animals (except parasites, species transported by host/vector)		
	Parasites on animals (including species transported by host and vector)		
	Contaminant on plants (except parasites, species transported by host/vector)		
	Parasites on plants (including species transported by host and vector)		
	Seed contaminant		
	Timber trade		
	Transportation of habitat material (soil, vegetation, …)		
		Aquaculture	*228*
		Packaging materials	*56*
Transport - stowaway	*Angling/fishing equipment*		
	Container/bulk		
	Hitchhikers in or on airplane	**Aviation**	**27**
	Hitchhikers on ship/boat (excluding ballast water and hull fouling)	Shipping	921
	Ship/boat ballast water		
	Ship/boat hull fouling		
	Machinery/equipment		

	People and their luggage/equipment (in particular tourism)		
	Organic packing material, in particular wood packaging		
	Vehicles (car, train, …)	**Land transport**	**297**
	Other means of transport		
Corridor	Interconnected waterways/basins/seas	Lessepsian migrants	499
		Inland Canals	66
	Tunnels and land bridges		
		Railroads and Highways	*38*
Unaided	*Natural dispersal across borders of invasive*		

Issues were also raised in distinguishing between the **Stowaway** and **Contaminant** pathways. All agreed that an alien species was a contaminant if it had a trophic or biotic relationship to organisms or items being transported and was to some extent dependent on them for survival. Similarly, all agreed that an alien species should be considered a **stowaway** if it had no trophic or biotic relationship to the organisms or items being transported. The issue revolved around where to draw the line between these extremes, i.e. where there is a trophic or biotic relationship with the items or goods but the taxa can survive in their absence. There were also similar discussions between the experts regarding the distinction between the **Escape from confinement** and **Release in nature** pathways, suggesting the definitions around these two terms may need refinement or additional clarity through examples.

A number of points were also raised about the definitions themselves. For example, based on the current pathways and their definitions none could be applied to contaminated animal or plant products such as wood furniture, wool & woollen items, leather & leather items. The definition provided for the **Natural dispersal** pathway was felt to be confusing, specifically its reference to only applying to species that "*have been introduced through pathways 1 to 5*", which could be incorrectly interpreted to mean that it only applies to species initially introduced by pathway subcategories 1 to 5 (**Biological control**, **Erosion control / dune stabilisation**, **Fishery in the wild**, **Hunting**, and **Landscape / flora / fauna "improvement" in the wild**). The correct interpretation, however, is that the reference to "pathways 1 to 5" refers to the pathway categories (**Release in nature**, **Escape from Confinement**, **Transport – contaminant**, **Transport – stowaway**, and **Corridor**), rather than sub-categories, and therefore applies to the subsequent spread, by natural dispersal, of any species from a region into which they had been introduced by any of the pathways within these 5 pathway categories.

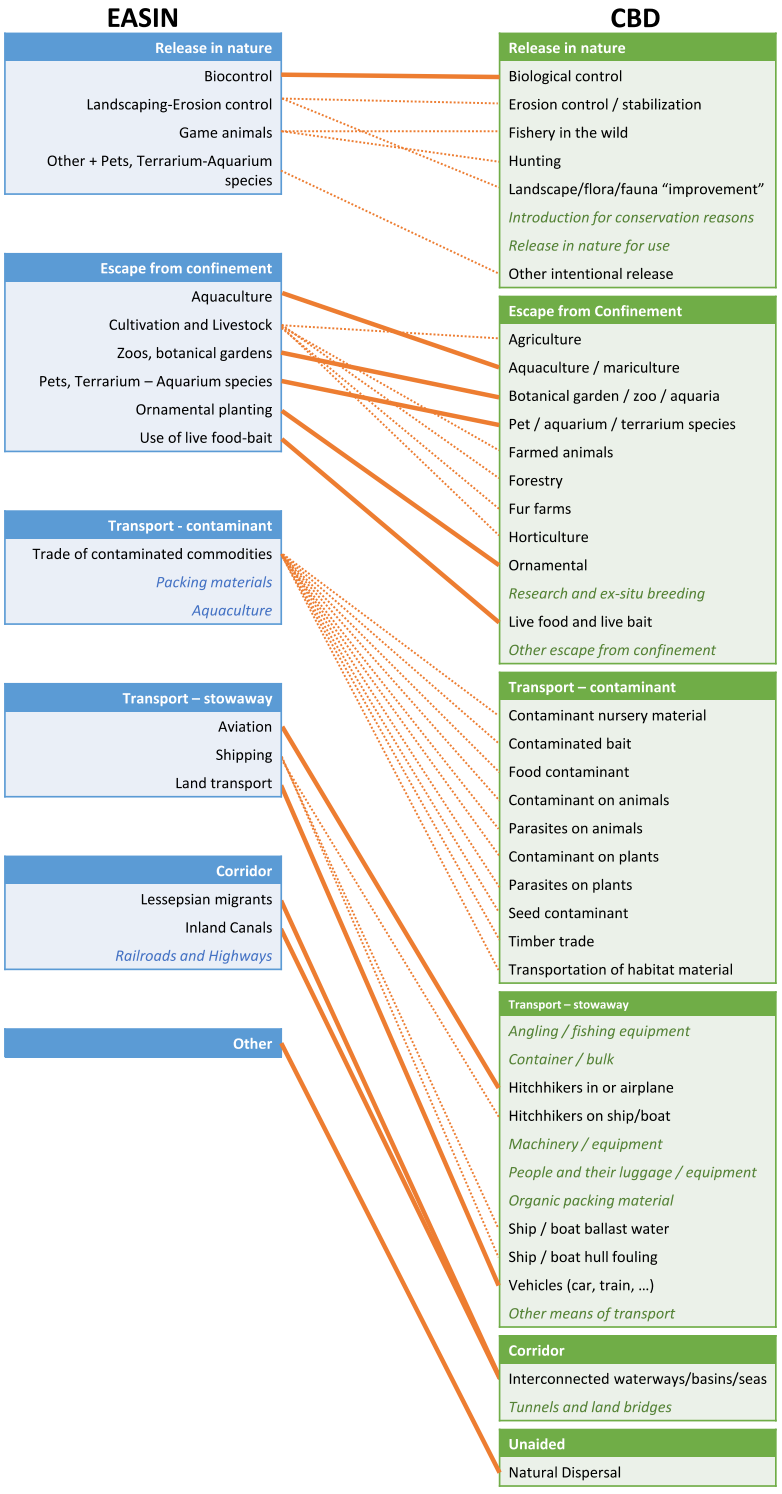


Figure 3 Schematic providing a visual representation of alignment between pathway terminologies used in EASIN database against the CBD pathway categorisation scheme. Solid thick lines represent EASIN pathways that correspond to a single CBD pathway while the think dotted lines represent EASIN pathways that could align to multiple CBD pathways. Pathways in italics are EASIN or CBD pathways that did not have a direct match in the other categorisation scheme. Schematic created from data presented in Table 1 of Tsiamis et al. 2017.

Any ambiguity or confusion surrounding categories, and their scope, in a classification scheme will give rise to inconsistencies across and within datasets, particularly where the categorisation process is undertaken by many different experts. This is because individual experts make decisions with high levels of uncertainty where ambiguities exist and so there is likely to be high variability in the choices made by different experts. To minimise the effect that this had on the pathway assignments in the reclassification of the EASIN pathways, the team of experts discussed areas of confusion with one another and shared the outcomes across the group, developing the classification through consensus. Additionally, the pathway allocations were peer-reviewed by experts and disagreements were investigated by the project team.

One final issue that was encountered is not directly related to the classification scheme itself but to how pathways relate to species. During the peer-review which followed the reclassification of the EASIN pathways it became apparent that some invertebrates had been assigned to pathways that did not initially make sense for animals such as **Forestry**, **Horticulture** or **Ornamental**. In the majority of cases these taxa had been assigned to these pathways as they were transported outside their native range on trees introduced for forestry or plants introduced for horticulture or ornamental purposes. Although in this situation forestry is the ultimate reason for the introduction of the species, the pathway by which the species was transported was by being a **Contaminant on plants,** with the **Forestry** pathway belonging to the plants/trees on which they were a contaminant. This issue of linked or dependent pathways, and our suggestions for dealing with it are discussed later in this document (**Dependent pathways** section).

OBJECTIVES

The application of the CBD pathways categorisation (CBD 2014a) has the potential to improve understanding of the most relevant pathways of introduction of alien species. However, detailed guidance on how to interpret the definitions set in the document above is lacking and, as discussed above, can lead to inconsistency in application of the classification.

The aim of this document is to provide guidance on how to interpret the definitions of the CBD pathways categorisation system for alien species, including examples from a number of environments and taxa, to contribute to the intentions set out by the CBD (2014b) which invited “the Invasive Species Specialist Group of the International Union for Conservation of Nature and other technical partners to continue and complete the work on pathway analysis, and to continue to develop a system for classifying invasive alien species based on the nature and magnitude of their impacts”.

A discussion on definitions and terminology is included, along with examples of applying the classification system to species information. The description of each subcategory is also accompanied by explanations to resolve confusion with other similar subcategories, and also, in this context, examples are provided as appropriate.

CBD Introduction Pathway Descriptions

Overview

As mentioned previously the CBD pathway categorisation builds upon the framework proposed by Hulme *et al.* (2008), using the six pathway types proposed (Release, Escape, Contaminant, Stowaway, Corridor and Unaided) and building upon them through the addition of 44 pathway subcategories nested within the main categories (**Figure 1**). The six main categories can be distinguished on the basis of whether the alien species was introduced intentionally, unintentionally as a contaminant or stowaway with other organisms/goods/equipment or vehicles, travelled through a corridor or arrived naturally from other regions in which it is alien (**Figure 4**). The 44 subcategories are nested within these six pathway categories and separate out the different reasons or ways in which species are either intentionally or unintentionally transported or disperse.

In the following section the six pathway categories and their corresponding sub-categories are listed and detailed. For each pathway there is a subsection beginning with the pathway title (in bold) followed by a summary sentence (indicated in italics) and then an expanded description. In addition to descriptions of the pathway, potential areas of confusion between pathways are also highlighted and the distinguishing features noted. At the end of each pathway section examples of the pathways are provided.

The following section also contains figures that outline the decision process that can be used to categorise pathway information to the 6 main pathway categories (**Figure 4**) and also how to assign pathway subcategories within each category (**Figure 5** to **Figure 9**). Each of these figures actually show a restricted part of a larger decision process flowchart outlining the entire decision process across all categories, which is provided as a supplementary file in a pdf format. Therefore the flowchart is a useful tool to preliminarily identify which pathways better reflect a given introduction event. However, the correct allocation of a pathway should be done only after carefully reading the full description of the considered pathway.

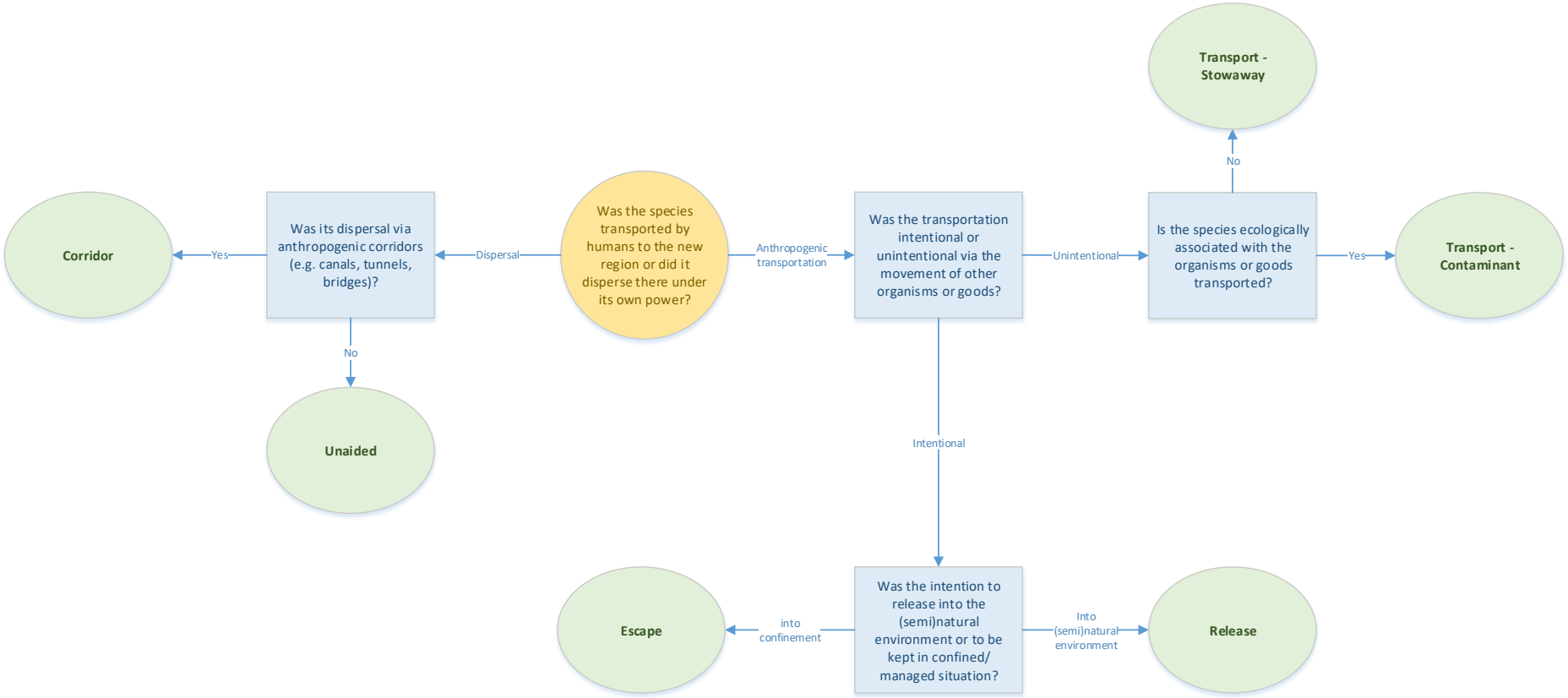


Figure 4 Schematic showing the six main pathway categories in the CBD pathway categorisation system and outlining the decisions process for differentiating between these pathway categories. In order to use the diagram start with the question in the yellow circle and then progress round the diagram by answering the questions in the blue boxes, following the arrows with the appropriate answers, until ending at one of the six main pathway categories (green oval). It is important to note that for species can be arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

1 Release in Nature

Species intentionally transported and released in the (semi)natural environment with little to no dedicated anthropogenic assistance

Description

The main pathway category **Release in nature** and corresponding pathway subcategories, describe situations in which species are intentionally transported and introduced by humans to regions in which they are non-native. Species introduced through **Release in nature** pathways are typically introduced into (semi)natural environments rather than into confined or controlled situations such as glasshouses or arable fields. Additionally, there is typically little to no dedicated anthropogenic assistance for the species, hence little to no provision of food and cover, or tending for plants. In general, species are expected to be self-sustaining post-release, but there are cases in which the frequent/regular releases of individuals in the environment is necessary to keep the population size fit to the purpose (e.g. fishing, hunting, harvesting, etc.). In all cases the species under this category are introduced deliberately, for one or more reasons, the most common of which are hunting or fishing (for meat, resources or sport); to provide a service; or for ornamental or cultural reasons.

Similar or Related pathways

The **Release in nature** pathway category, and pathways contained within, can be confused with the **Escape from confinement** pathway category and its pathways. The main discriminating features between these two categories focus on the underlying motivation or primary "intention" of the introduction of the alien species. In particular, the **Release in nature** category refers to species intentionally and directly released into the wild to serve a specific purpose (even though this may have entailed the species being kept for a period in captivity or controlled conditions prior to the release). The **Escape from confinement** category, on the other hand, refers to species brought into the region to be permanently kept in captivity or otherwise controlled environments (e.g. fenced parks, glasshouses, arable fields, etc.), in which they were reliant on humans (e.g. farmed animals, cultivated plants, pets, etc.) but from which they escaped into the wild, or from where they found their way to the (semi)natural environment due to accidental or irresponsible releases. Therefore, the discriminating features focus on the primary "intention" of the introduction.

For example, accidental or irresponsible release of live organisms from confinement (e.g. dumping of pets by irresponsible owners or the release of fur farmed animals by animal welfare groups) belong to the **Escape** category, not to the **Release** one, as the animals were brought into the country to be kept in captivity, not to be released into the wild.

No confusion should exist with the **Transport – contaminant** or **Transport – stowaway** pathways as they entail the unintentional introduction of species as contaminants or stowaways, and not the intentional introduction of the alien species to be utilised or collected. In other words, the **Release** pathways (and **Escape** pathways) can be distinguished from both the **Contaminant** and **Stowaway** pathways on the basis of whether the species was intentionally transported to the new region (**Release** & **Escape**) or whether it was unintentionally or accidentally transported to the new region (**Contamination** & **Stowaway**). In this case the discriminating feature is the "intentionality" of the transportation of an alien species in areas outside its native range.

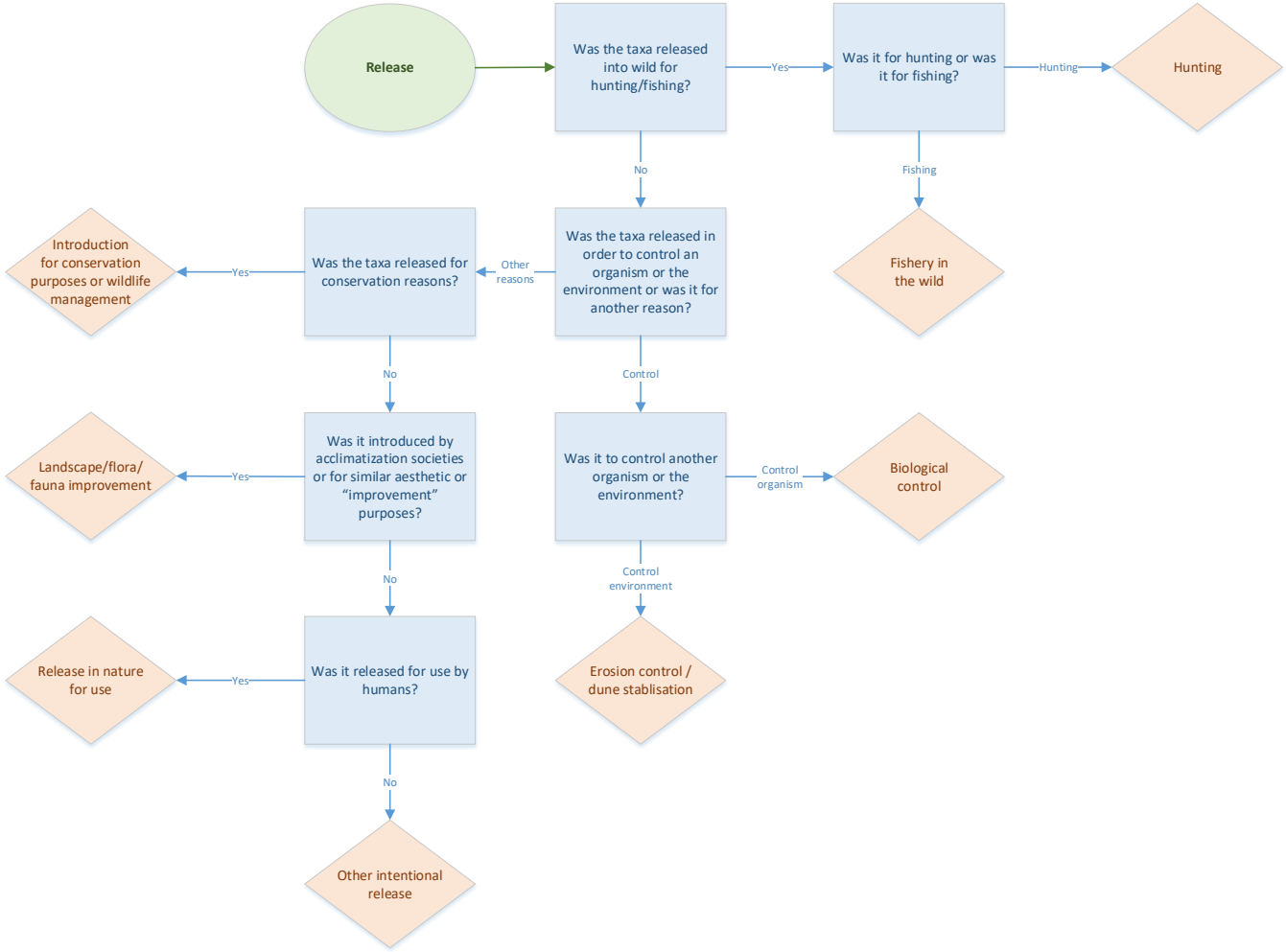


Figure 5 Schematic showing the pathway subcategories within the **Release in nature** category and outlining the decision process for assigning species to these pathways. To use this schematic begin at green oval for the category and proceed through the questions in the blue boxes by following the arrows with the appropriate answers until reaching a subcategory (red diamond). It is important to note that a species can have arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

1.1 Biological Control

Species released into the (semi)natural environment with the purpose of controlling the population(s) of one or more organisms

Description

There are many different approaches to biological control but essentially all involve the control of target organisms, typically pests or pathogens, by so-called natural enemies of the target organism. Biological control using alien species has most commonly been used to control pests and/or pathogens in agricultural, farming, or forestry systems or control those that pose a direct threat to human health, however it has also been used to control IAS.

There is potential for confusion in the classification of biological control agents allocating them to an **Escape** type pathway rather than the current pathway located within **Release** pathway category, particularly for situations in which the species was introduced into confined environments (e.g. glasshouses or enclosed fields). In the majority of these cases, however the confinement/control operates upon or is targeted at the species being cultivated or farmed and not the biological control agent (or even the pest/pathogen), which are typically relatively unrestricted and are able to leave the area of confinement or control relatively easily. In such circumstances, where it is probable or expected that some individuals will leave the area of confinement/control, then the **Biological control** pathway is still appropriate. If however, the species were released into situations with control measures in place to prevent the control agent from leaving the area of confinement/control then the **Other escape from confinement** pathway within the **Escape from confinement** category is more appropriate and should be applied instead. However, introductions for biological control should always be considered under the **Release** category, regardless of whether they are released into agricultural/production system (particularly in confined systems like greenhouses) from where they could successively escape into the (semi)natural environment (even if this seems to contradicts the definition of the **Release** category), or whether they are released directly into the (semi)natural environment (e.g. for the control of other IAS).

Similar or Related pathways

Species introduced for biological control have most commonly been used in attempts to control pests and pathogens in agricultural, farming or forestry systems and therefore it may seem intuitive to assign them to the relevant **Escape** pathway for the system into which they were added for biological control purposes (e.g. **Agriculture**, **Aquaculture / Mariculture**, **Forestry**, **Farmed animals**). The primary purpose, however, of the introduction is these cases is for the biological control of a target alien species and therefore the **Biological control** pathway is the appropriate pathway.

This pathway may overlap with or be confused with the pathway **Introduction for conservation purposes or wildlife management** in situations where an alien species has been introduced to aid in the conservation of an endangered species, for example by controlling a pest or pathogen species that affects the endangered species. In these situations however, the primary purpose of the species introduction is still for biological control and therefore it should be assigned to the **Biological control** pathway.

Examples

The release of the Cane toad (*Rhinella marinus*) from the American continent to many regions around the world (e.g. Australia, Puerto Rico, Hawaii) is a typical example of introduction carried out to control pests (such a mice and beetles) in agricultural systems (Lever 2001).

The Harlequin ladybird (*Harmonia axyridis*), native to Asia, was introduced to Glasshouses, Orchards and gardens in several regions of Europe and North America to control aphids. It subsequently spread, or was unintentionally transported, into surrounding regions via other pathways, e.g. **Natural Dispersal**, or pathways in **Transport – contaminant** and **Transport – stowaway** categories.

The Mosquito fish (*Gambusia* spp.) has been introduced from North America throughout the world as a mosquito-control agent.

1.2 Erosion control / dune stabilisation (windbreaks, hedges, …)

Species released into the (semi)natural environment to control the environment or to act as physical barriers (e.g. stabilise substrate, control animal movement or to manage the action of wind, water, or fire).

Description

Some species can have a dramatic effect upon the environment in which they occur by providing a stabilising effect on the environment and/or acting as barriers to natural processes or the movement of animals (e.g. dune & hillside stabilisation, hedges, wind breaks, erosion control, fire control). This subcategory, specifically applies to species with these types of environmental control properties that have been introduced intentionally into areas or regions where they were alien to take advantage or make use of these properties.

This pathway only relates to the control of animals or the natural environmental factors and therefore does not cover management or control of artificial or human-mediated factors such as pollution (e.g. bioremediation and waste management).

Similar or Related pathways

This pathway can seem to overlap with the pathways **Farmed animals** or **Agriculture**, for example where species have been introduced into agricultural contexts to provide barriers to prevent the movement of animals and livestock or to protect crops (e.g. windbreaks, hedges). However, the species themselves are not being farmed or cultivated to produce crops but rather are being used for their barrier properties and, therefore, the **Erosion control / dune stabilisation** pathway is most appropriate. In some cases however the species may be serving multiple purposes such as providing crops (fruit bushes) and also acting as barriers in which cases the species should be assigned to both pathways.

Similarly, the **Erosion control / dune stabilisation (windbreaks, hedges, …)** subcategory may be confused with the **Landscape/flora/fauna "improvement" in the wild**, with which some overlap may be envisaged. However the key difference is that the latter subcategory refers to introductions occurred for aesthetic reasons.

This pathway may also be confused with the **Introduction for conservation purposes or wildlife management** pathway. However, to discriminate the two categories it is important to focus on the objectives of the introduction. For example, if a species is being used as barriers or for environmental control to maintain or create specific conditions required for the conservation of another endangered/protected species or habitat type (characterised by the presence of such other species) then the objective is not the conservation of the species introduced. In these situations however since the primary purpose of the species being introduced is for its barrier and/or environmental control properties and not for being conserved itself, the **Erosion control / dune stabilisation** pathway is the appropriate pathway.

This pathway may also be confused with the **Release in nature for use** or the **Other intentional release** pathways. The key distinction between the **Erosion control / dune stabilisation** pathway and these two relatively miscellaneous **Release** type pathways is that species in the **Erosion control / dune stabilisation** pathway are introduced to a region specifically for properties that ensure they are effective barriers or controls of animal movement, substrate movement, or the actions of wind, water, or fire. In contrast the generic/miscellaneous pathways, **Release in nature for use** and **Other intentional release**, should only be used in situations where none of the more specific pathways within the **Release in nature** category are appropriate. For example, other releases apparently aimed at environmental "control", such as those aimed at controlling artificial/human mediated pollutions, shall be considered under the **Release in nature for use (other than above, e.g. fur, transport, medical use)** subcategory as the **Erosion control / dune stabilisation (windbreaks, hedges, …)** subcategory is specific to natural environmental factors (wind, water, fire).

Some confusion may arise in relation to the subcategory **Transportation of habitat material (soil, vegetation,…)**, which however refers by definition only to contaminants introduced accidentally, hence it can easily distinguished by **Erosion control / dune stabilisation (windbreaks, hedges, …)** as the latter only refers to the species introduced intentionally, e.g. in bioengineering or restoration projects.

Examples

European marram grass (*Ammophilla arenaria*) is adapted to growing on sand dunes. It is native to Europe and western Asia but has been introduced for dune stabilisation to a number of other countries where it has become problematic.

Crown vetch (*Securigaria vera*), native to Asia, Africa and Europe, produces a deep, tenacious, complex root system and coupled with thick, fern-like leaves provides erosion control where it is used as a ground cover. It was for this reason, erosion control, that it was introduced to the USA.

1.3 Fishery in the wild

Fish and other aquatic animals released into the (semi)natural environment to provide additional or alternative subsistence and/or commercial or recreational fishing opportunities

Description

Fishing is an important economic and/or recreational activity in many countries. Many fish species have been taken from their native range and introduced to regions where they are alien to create alternative or novel opportunities for commercial & recreational fishing, or to provide an additional or more productive source of food for either people or animals. Fish that are introduced can impact biodiversity and habitats through a variety of mechanisms, including predation or competition, or have other unintended effects causing significant changes to the invaded ecosystem.

This pathway covers introductions of species for these reasons to both freshwater and marine environments. Furthermore it is not restricted to just fish species but also aquatic invertebrates - such as Molluscs, Crustacea, Jelly fish, Echinoderms, etc. - that have been released directly into the environment to be "fished" or otherwise harvested. This pathway also includes situations where species are introduced to modified or artificial environments but only where they are connected, and with free access, to (semi)natural water systems (e.g. not contained or confined). This pathway does not include pest, pathogens or any other species that are unintentionally introduced along with the species (i.e. as contaminant) being introduced for fishing.

Similar or Related pathways

This pathway is similar to or may be confused with the **Aquaculture / mariculture** pathway within the **Escape from confinement** pathways (or even possibly the **Farmed animals** pathway although the later should only be used for farming of terrestrial animals). A key difference between these categories is whether the species was intentionally and directly released into the (semi)natural environment (**Fishery in the wild**) or whether it was introduced and kept in situations that were confined or segregated from the natural watercourses (e.g. cages, tanks, artificial ponds) before subsequently escaping into the natural environment (**Aquaculture / mariculture**). An additional important distinction is that in general the pathways within the **Escape from confinement** category, such as the **Aquaculture / mariculture** pathway, involve a notable degree of husbandry of the organisms while in confinement prior to their escape. In contrast the pathways under the **Release in nature** category typically involve little to no husbandry after the initial introduction.

Situations that should be assigned to the **Pet / aquarium / terrarium** pathway could also potentially be considered within the **Fishery in the wild** pathway, or perhaps more likely the **Other intentional release** pathway, in cases where private collectors or hobbyists have illegally released species from their collection. It may seems counterintuitive to assign situations in which species were intentionally released to an **Escape from confinement** pathway rather than a **Release in nature** pathway. The reasoning underlying the inclusion within the **Pet / aquarium / terrarium** pathway is that the species were brought into the region to be kept in confinement in private collections and, therefore, the release can be considered as 'facilitated escape' and classified as the **Pet / aquarium / terrarium**.

The **Fishery in the wild** pathway may also be confused with the **Hunting** pathway. In general the former is used for aquatic animals and the later for terrestrial animals. The situation, however, is less obvious in case of non-fish vertebrate species that inhabit freshwater and marine environments, such as amphibians (e.g. frogs, newts, and

salamanders), aquatic reptiles (e.g. turtles, terrapins, crocodilians, snakes, etc.), marine or aquatic mammals, or aquatic birds released to be harvested from the wild for human consumption or similar purposes. The **Hunting** pathway should be used for species from these groups as "hunting" rather than "fishing" is the term that would be most commonly associated with these groups ("fishing" is not a term that would be typically ever be used for the catching and harvesting of mammals or most reptiles) and therefore this assignment is the most intuitive and least likely to cause confusion.

Examples

The introduction of the Nile perch (*Lates niloticus*) to Lake Victoria, in Eastern Africa to boost the fishing industry in the 1950s, in the belief that the species would feed on the Cichlid fauna making their biomass available for food as suitable table fish. In the early 1980s an explosive population explosion of the Nile perch, in addition to overfishing and competition, resulted in dramatics declines and losses of the native Cichlid fauna altering the lake ecosystem dramatically (Ogutu-Ohwayo 1990, Goldschmidt 1996).

Common carp (*Cyprinus carpio*) has been introduced both intentionally and unintentionally in many countries worldwide via various pathways, including releases into natural environments to provide food source and also for angling/sport fishing.

1.4 Hunting

Animals released into the natural environment to be hunted for food and/or to provide recreational hunting opportunities (including collection of hunting trophies)

Description

In many countries, alien species have been released deliberately into the (semi)natural environment with the specific purpose to be hunted and/or harvested either for sport (recreational/trophy hunting) and/or to be exploited for food. Species introduced for hunting, so-called game species, are typically terrestrial vertebrates and are often medium to large herbivores or predators, particularly in the case of recreational hunting.

This pathway should only be used for species being intentionally and directly released for hunting in the (semi)natural environment, as described above, and should not be used for species unintentionally introduced (e.g. as contaminants or stowaway) along with the species being introduced for hunting.

Similar or Related pathways

This pathway is similar to or may be confused with two pathways in the **Escape from confinement** category, specifically the **Farmed animals**, or **Fur farms** pathways. The **Hunting** pathway may be confused with the **Farmed animals** pathway in situations where species are introduced to provide food, agricultural products, or to be used as working animals. The **Hunting** pathway covers situations where species are introduced into (semi)natural environments to be hunted/harvested from the wild when required, often receiving little or no husbandry or management (e.g. supplementary feeding, medical treatment, etc.) after release and with the aim of producing a self-sustaining population in the (semi)natural environment. In contrast animals within the **Farmed animals** pathway are

typically kept, cared for, and bred in confined or controlled environments, such as fields, stables, pens, cages, etc. Furthermore, in the **Farmed animals** pathway the expectation is that the majority of individuals kept will be utilised for the intended purpose while in the **Hunting** pathway only a proportion of the individuals are likely to be utilised as some are likely to evade capture or harvest. The distinction between these pathways can be quite subtle particularly when farmed species are kept under loose confinement (including in very large game reserves) or where species kept and raised in confinement are released from confinement to be harvested by hunting. In these situations the decision on whether the **Farmed animals** or **Hunting** pathway is more appropriate will depend upon the proportion of the life spent in confinement, or under human care and control, and/or whether the expectation was that all, or at least the majority, of individuals are expected to be recaptured or utilised (e.g. hunted). For example, alien ungulates are often introduced in game farms for either conservation (and tourist) purpose, for food or for hunting. The allocation of each introduction event to the appropriate pathway category needs to be assessed on a case by case basis.

The **Hunting** pathway and the **Fur farms** pathway may be confused in situations where species are introduced into the (semi)natural environment for their fur. In the case of the **Hunting** pathway the species are released into the wild from which they are then hunted for fur. In contrast, in the case of the **Fur farms** pathway, they are kept, raised and bred in captivity or controlled environments (such as pens or cages), often on a large or commercial scale, to be exploited specifically for their fur when required.

The **Hunting** pathway may also be confused with the **Fishery in the wild** pathway as they cover similar reasons for introduction but in different environments. In general the latter is used for aquatic animals and the former for terrestrial animals. The situation, however, is less obvious in case of non-fish vertebrate species that inhabit also freshwater and marine environments, such as amphibians (e.g. frogs, newts, salamanders), aquatic reptiles (e.g. turtles, terrapins, crocodilians, snakes, etc.), marine or aquatic mammals, or aquatic birds released to be harvested from the wild for human consumption or similar purposes. The **Hunting** pathway should be used for the species from these groups as “hunting” rather than “fishing” is the term that would be most commonly associated with these groups (“fishing” is not a term that would be typically ever be used for the catching and harvesting of mammals or most reptiles) and therefore this assignment is the most intuitive and least likely to cause confusion.

There might also be some subtle overlap/confusion between the **Hunting** and the **Release for use** pathways. Specifically in the case of species introduced into the wild primarily for their fur/hide or other body parts (excluding meat for food or hide/body parts as trophies), and which are hunted to be harvested. In these cases the discriminating feature is the purpose of the hunt, with **Release for use** applying when the hunt is primarily not for food or sport (or at least only secondarily for the food) and **Hunting** applying when the hunt is primarily for food or sport. For example the raccoon dog (*Nyctereutes procyonoides*) is a native from East Asia introduced in Europe specifically as a fur game species, and as such should be considered under the **Release for use** pathway.

Some confusion may also exist with the **Farmed animals**, **Pet / aquarium / terrarium species** or **Other escape from confinement** pathways. For example, in case of escape of

species used for hunting purposes, such as the ferret (*Mustela furo*) used for hunting rabbits, or the falcons and other birds of prey (including hybrids) used in falconry. In these cases the species used within the animal-aided hunting techniques (e.g. falconry, ferreting) represent the means, not the objective of the hunt, and as such do not qualify for the **Hunting** subcategory. The issue of what pathway is correct in these situations, however, will depend upon the primary purpose for which the species is being kept. Traditionally the animals used for animal-aided hunting would primarily have been kept for hunting and therefore would qualify as working animals placing them in the **Farmed animals** pathway. Over time this hunting role has become less important and in many cases these species are now primarily kept as part of domestic collections, despite being taken out into the wild to hunt (often as a bonding and/or enrichment activity), placing them in the **Pet / aquarium / terrarium species** pathway. In cases where the primary purpose of these hunting species is unknown they can be assigned to the **Other escape from confinement** pathway.

Examples

Hunting is generally considered one of the most common motivations for the introduction of mammals, particularly Artiodactyla and Lagomorpha, and birds, particularly Galliformes and Anseriformes (Monaco et al. 2016). The aoudad (*Ammotragus lervia*), for example, is a North African caprid successfully introduced as a game species in mountainous desert regions of Texas, New Mexico, and California in the US and Spain (Cassinello et al. 2006).

The American Bullfrog (*Lithobates catesbeianus*) is a freshwater species introduced in many areas of the world with the purpose to create wild stocks to be harvested for human consumption as a gourmet or delicacy for their legs.

1.5 Landscape / flora / fauna "improvement" in the wild

Species released into the (semi)natural environment for aesthetic reasons only (including in the past by acclimatization societies or settlers) to "improve" the flora or fauna and/or to make new regions more familiar

Description

Intentional introductions of alien species driven prominently by aesthetic reasons were particularly common in the past, although may occur still today. This activity reached a peak in the 19th and early 20th centuries with the establishment of dedicated acclimatization societies aimed at "improving" or "enriching" the landscapes in lands newly colonized by Europeans throughout the world. The perception of colonists was that the new lands in which they were settling was impoverished in terms of their fauna and flora, coupled with a nostalgic desire to have familiar species present, precipitated the incorporation of organizations to import and introduce alien species.

While Acclimatization societies and their activities have decreased significantly over the last century (due to the reduction in the establishment of new colonies and the realisation of the problems that can results from the introduction of alien species) releases by individuals/groups carried out to "improve" the flora or fauna assemblage through the introduction of alien species are still frequent.

Habitat restoration and engineering works, including the realisation of green infrastructures (e.g. to increase interconnectivity between environments) may also fall within this category.

Similar or Related pathways

There can be a high degree of overlap between the **Landscape / flora / fauna "improvement" in the wild** pathway, the **Hunting** pathway and the **Fishing in the wild** pathway as acclimatization societies also introduced species so that they could be hunted or fished. If the hunting/fishing were the primary reason for the introduction then the relevant specific pathways should take precedence (even if the introduction was by an acclimatization society). However if primary reason for the introduction of the species was for aesthetic purpose, such as making the new land feel more like home and/or to enhance a fauna that the colonists regarded as being impoverished then the **Landscape / flora / fauna "improvement" in the wild** should be assigned. The same approach should be used to distinguish this pathway from the **Introduction for conservation purposes or wildlife management**, which is characterised by the specific purpose of the introduction that aims at ensuring the long term survival of the alien species and is therefore not for aesthetic reasons only.

There may also be confusion between the **Landscape / flora / fauna "improvement" in the wild** pathway and several of the pathways in the **Escape from confinement** category in situations where familiar flora or fauna were transported by Acclimatization societies or colonists to be cultivated, farmed or kept as working animals, for display or kept as pets. The distinction between the **Landscape / flora / fauna "improvement" in the wild** pathway and the pathways within the **Escape from confinement** category is that in the former species are directly released into the (semi)natural environment to form self-sustaining populations for aesthetic reason only, while in the latter alien species were transported to a new region with the primary purpose of being kept in captivity, or in controlled environments, to serve a particular purpose or role and are typically cared for and/or managed.

Examples

A representative example is the introduction of the European starlings (*Sturnus vulgaris*) to the US, which was intentionally released by an acclimatization society with the aim of introducing to the country all the birds quoted in Shakespeare's works.

As pointed out by Monaco et al. (2016) alien plants are used by hunters for habitat restoration (e.g. to create shelter, hedges, small wetlands and woodlands) or to ensure the supply food resources to game (game crops, artificial feeding; e.g. topinambur *Helianthus tuberosus* in Poland.

The case of the Italian wall lizard (*Podarcis sicula*), introduced in South California in 1994 (Kirschbaum and Pauly 2016), and the European common wall lizard (*Podarcis muralis*) introduced in Cincinnati, Ohio (USA) circa 1950 (Deichsel and Gist 2001), are both linked to releases by tourists returning from a journey to Italy, respectively from Sicily and from Lake Como area in northern Italy, where the animals were caught in the wild.

Introductions for landscape "improvement" include the central American *Opuntia* and *Agave* species, which are typical floral elements planted in some Mediterranean islands and regions to attract the attention of tourists looking for 'Wild West' landscapes. Similarly the

Mediterranean cypress (*Cupressus sempervirens*), apparently a native to the Eastern Mediterranean region, was introduced since ancient times to many areas with similar climate, including the whole Mediterranean region, where it became part of the typical landscape, i.e. in Tuscany.

1.6 Introduction for conservation purposes or wildlife management

Species released into the natural environment to aid in their conservation or wildlife management

Description

Within the context of conservation initiatives, the introduction of species, along with other reintroduction or translocation programmes, is sometimes an option to secure long-term survival of endangered/protected species. The potential issues with introductions can be manifold both to the focal species and the source and destination areas. This can be the only available option in case of a species whose original range is currently unsuitable for its survival and where it would be impossible or impractical to remove the main threats, and only a few individuals are left either in a small part of its range or only in captivity. To ensure the long term conservation of the population of that species an alternative area may be identified for its release in (semi)natural environments, even outside its native range, e.g. where the threats to its survival are not present. In some cases the introduction can be with the purpose of improving genetic diversity of a small or declining population; whether this is still considered an alien introduction or not is under debate and will be context dependent. Therefore, the need to provide adequate documentation explaining the context is critical.

This subcategory includes the release of alien animals and plants for wildlife management purposes, e.g. to provide food and cover to native species (e.g. release of animals as prey for endangered predators, or planning of trees to include opportunities for feeding, nesting, etc.).

Similar or Related pathways

This pathway may be confused with multiple pathways in situations where alien species are being utilised in association with the conservation of another species. For example alien species may be introduced to biologically control a pest or pathogen affecting an endangered species. In these situations the species should be assigned to pathway that is appropriate for the reason that species is being used (e.g. **Biological Control** is the case of species being used to control a pest or pathogen of an endangered species). See the similar or related pathways sections for **Biological control** and **Environment Control & Barriers** for more details.

There might be some subtle overlap/confusion with the **Hunting** pathway, for example in the case of species which are hunted to be properly managed. However, at least in this case the discriminating feature is the purpose of the hunt, which is not for food (or at least only secondarily for the consumption of meat), but rather for wildlife management purpose related to the conservation of the species targeted.

Some confusion with **Hunting** pathway could raise in situations where this activity is identified as an indirect pathway of introduction of plants used by hunters for wildlife

management purposes (e.g. habitat restoration, improvement of food/cover resources, etc.). However, as the release does not directly involves the species to be hunted, the correct subcategory is clearly **Introduction for conservation purposes or wildlife management**. This consideration should also clarify any doubt in relation to other subcategories such as **Release for use** and the **Landscape / flora / fauna "improvement" in the wild**, which are not primarily aimed at ensuring the long term survival of the alien species actually released in the (semi)natural environment.

Examples

The Guam rail (*Hypotaenidia owstoni*) is a bird endemic to Guam (US territory in Micronesia, Western Pacific), which is currently considered extinct in the wild as a result of predation by the introduced brown tree snake (*Boiga irregularis*). The survival of the species is guaranteed by the existence of around 160 birds that still survive in captive-breeding facilities in the US, including Guam. After the failure of a reintroduction programme in Guam, an attempt was made to ensure the conservation of the species by introducing a number of birds onto snake free islands nearby, including the introduction of the species to the Cocos Island (BirdLife International 2016).

1.7 Release in nature for use (other than above, e.g. fur, transport, medical use)

Species released into the natural environment to be used by humans for purposes other than hunting, fishing, environmental control/barriers, or conservation and not introduced for aesthetic reasons only

Description

Throughout history, plant and animal species that have been a source of food or fulfil an agricultural purpose have been taken from their natural ranges and introduced into new regions to enhance food production for the local human population. This has occurred both in areas where either traditional food sources were not present in newly colonized areas and were subsequently introduced; or, where human groups expanding their territories have discovered new species, returned home and introduced these species as a new food source.

Species have been introduced for other reasons- examples include for bioremediation, and waste management. Bioremediation is the process whereby a species is introduced into a damaged or polluted habitat to in some way improve the conditions that are present. Similar to bioremediation, waste management can incorporate processes whereby species are introduced into damaged or polluted habitat to improve the conditions that are present; or where species are used to breakdown large waste materials and remove contaminants such as heavy metals from manufacturing by-products.

The introduction of pollinating fauna, e.g. bees or other insects can also come under this category in situations where they are released in the (semi)natural environment and/or are left relatively unsupervised (see below for more details).

Similar or Related pathways

There might be some overlap/confusion with the pathways within the **Escape from confinement** pathway category, specifically the **Farmed animals**, **Pet / aquarium / terrarium species**, and **Other escape from confinement** pathways. For example, in case of escape of animals used for hunting, such as the ferret (*Mustela furo*) used for hunting rabbits, or the many species or hybrids of birds of prey used in falconry. In the examples however, the species used within the hunting activities are the typically kept in captivity and only released temporarily for training or during hunting before returning to captivity and as such do not qualify for the **Release in nature for use** pathway.

As mentioned in the description above the introduction of pollinating fauna can fall within this pathway, however it can also fall under the Farmed animals depending on the circumstances of the introduction. If the pollinators are introduced to (semi)natural environments and are left largely unsupervised and unmanaged, e.g. finding their own accommodation, not receiving supplementary feeding or medicines/treatments, etc. then they should be assigned to the **Release in nature for use** pathway. If in contrast they are kept in artificial hives and/or cared for and managed (e.g. receive supplementary feeding or medicines/treatments) then they should be assigned to the **Farmed animals** pathway.

Some overlap may exist with **Fishery in the wild** and the **Hunting** pathways, however these pathways specifically focus on species introduced intentionally in the (semi)natural environment for the sport aspect of their capture and/or the use of their meat for human or animal consumption. Further confusion with the **Hunting** pathway can occur around the case of species release into the wild primarily to be exploited for their fur/hides (or other body parts, with the exception of collection as trophies), and which are hunted to be harvested. However, at least in this case the discriminating feature is the purpose of the hunt, which is not for food (or at least only secondarily for the consumption of meat) hence the correct category is **Release in nature for use** pathway.

Some confusion may arise with **Erosion control / dune stabilisation (windbreaks, hedges, …)** subcategory, which however is specifically aimed at addressing introductions for the control of natural environmental factors (wind, water, fire) rather than controlling the artificial/human mediated pollutions, which in fact shall be considered under the **Release in nature for use (other than above, e.g. fur, transport, medical use)** subcategory.

Examples

The raccoon dog (*Nyctereutes procyonoides*) is a native from East Asia introduced as a fur game species in the European parts of the former Soviet Union about a century ago. The species successively spread to several European countries mostly through Natural dispersal.

1.8 Other intentional release

*Species released into the natural environment for reasons other than those covered in any other **Release in nature** pathways*

Description

This is an open subcategory where all situations that do not specifically fit the other **Release in nature** pathways can be assigned.

Any introduction carried out intentionally for biological control or dune stabilisation, or for the purpose of hunting or fishing for food, fur, or other uses, or for motivation related to the conservation of the species being released, or for aesthetic reasons, should not be considered here, as there are specific subcategories for such pathways.

For example, releases related to religious celebrations should be included here. They may, including 'prayer release' or 'merit release' of captive birds, which are widely practiced by Chinese inhabitants, e.g. Buddhists (Liu et al. 2013).

Similar or Related pathways

This subcategory may seem to fully overlap with the one about **Release for use (other than above, e.g. fur, transport, medical use)**, which however should be considered when a species is intentionally introduced for some specific use. Some confusion may occur also with the subcategory **Landscape / flora / fauna "improvement" in the wild** - which in fact should be considered only when the prominent reason behind the intentional introduction of a species is aesthetic - or the **Introduction for conservation purposes or wildlife management** – whose motivations are linked to the specific need to ensure the long term survival of the species being introduced itself.

Examples

Religious practises, which are considered a risk for dispersal of alien species, include those which facilitated the deliberate release of Common Mynas (*Acridotheres tristis*) in Hong Kong and Taiwan (see Gilbert et al. 2012, CABI 2014).

2 Escape from confinement

Species that have escaped from the confined or controlled environments where they were kept and cared for a number of purposes (e.g. provide food, resources, services or companionship)

The **Escape from confinement** category and pathways within refer to the unintentional escape into the wild of species intentionally brought into the region to be kept in confinement or controlled situations, such as zoos, aquaria, botanic gardens, agricultural systems, or private collections, for specific purposes (e.g. public display, decoration, scientific research, companionship, etc.). Unlike the pathways within the **Release in nature** category, which entailed the direct and intentional release of species in the wild with no intent to contain or use the species within a defined area, organisms in this pathway were initially purposefully imported or transported to confined or controlled conditions where they will be kept and/or used but ultimately from which they managed to escape. An additional distinction between the **Escape from confinement** pathways and the **Release in nature** pathways is that the former typical includes a notable degree of husbandry while the species is in confinement or under control while in the latter the individuals are often left to fend for themselves after release.

The **Escape from confinement** pathway also includes any accidental or irresponsible release of live organisms from confinement (e.g. dumping of pets by irresponsible owners, release of

animals by animal welfare groups, disposal of live food into the environment, or use of live baits in unconfined water systems). This may seem counterintuitive as the species are technically being released, but is due to species being assigned to the pathway reflecting the intention behind their presence in the region, namely to be kept in confined or controlled situations. Similarly, agricultural systems such as fields and also forests are not often truly confined but they are controlled, and as such shall be considered here.

Similar or Related pathways

The **Escape from confinement** pathways can often be confused with the **Release in nature** pathway and its sub-categories. The main distinguishing features are the intent behind the presence of the species in the region. If the intent was for the species to be directly introduced into (semi)natural environments, and then often left to their own devices, then the **Release in nature** pathway applies. If on the other hand the intent was for the species to be kept and/or used in a specific defined area (typically contained or controlled), from which it escaped, then the **Escape from confinement** pathway applies.

There may be additional confusion between the **Escape from confinement** and **Release in nature** pathways in situations where species being kept in confinement or under controlled conditions are intentionally allowed to escape or released (e.g. dumping by irresponsible owners, releases by animal rights groups). In these situations it should still be assigned to the appropriate **Escape from confinement** pathway (e.g. **Fur farms**, **Pet / aquarium / terrarium**, etc.) as this was the purpose for which the species was transported in the new region outside its native range.

Although they appear relatively distinct it is still possible for confusion to occur between the **Escape from confinement** pathways (as well as those in **Release in nature** category) and the pathways within the **Transport - Stowaway** or **Transport - Contaminant** categories. For instance a traveller may find a stowaway species in their luggage once back at home, or a person may find a contaminant species on a product they buy or receive, the person may then either release that species or keep that species in captivity from which it could escape. These situations could appear to be a release or an escape but are in actual fact either stowaways or contaminants. The pathways within the **Escape from confinement** and **Release in nature** categories can be distinguished from those in the **Transport - Contaminant** and **Transport - Stowaway** categories by the fact that the introduced alien species were intentionally transported to the new region in the former two pathways (**Escape from confinement** and **Release in nature**) while the transport was unintentional in the latter ones (**Transport - Contaminant** and **Transport – Stowaway**).

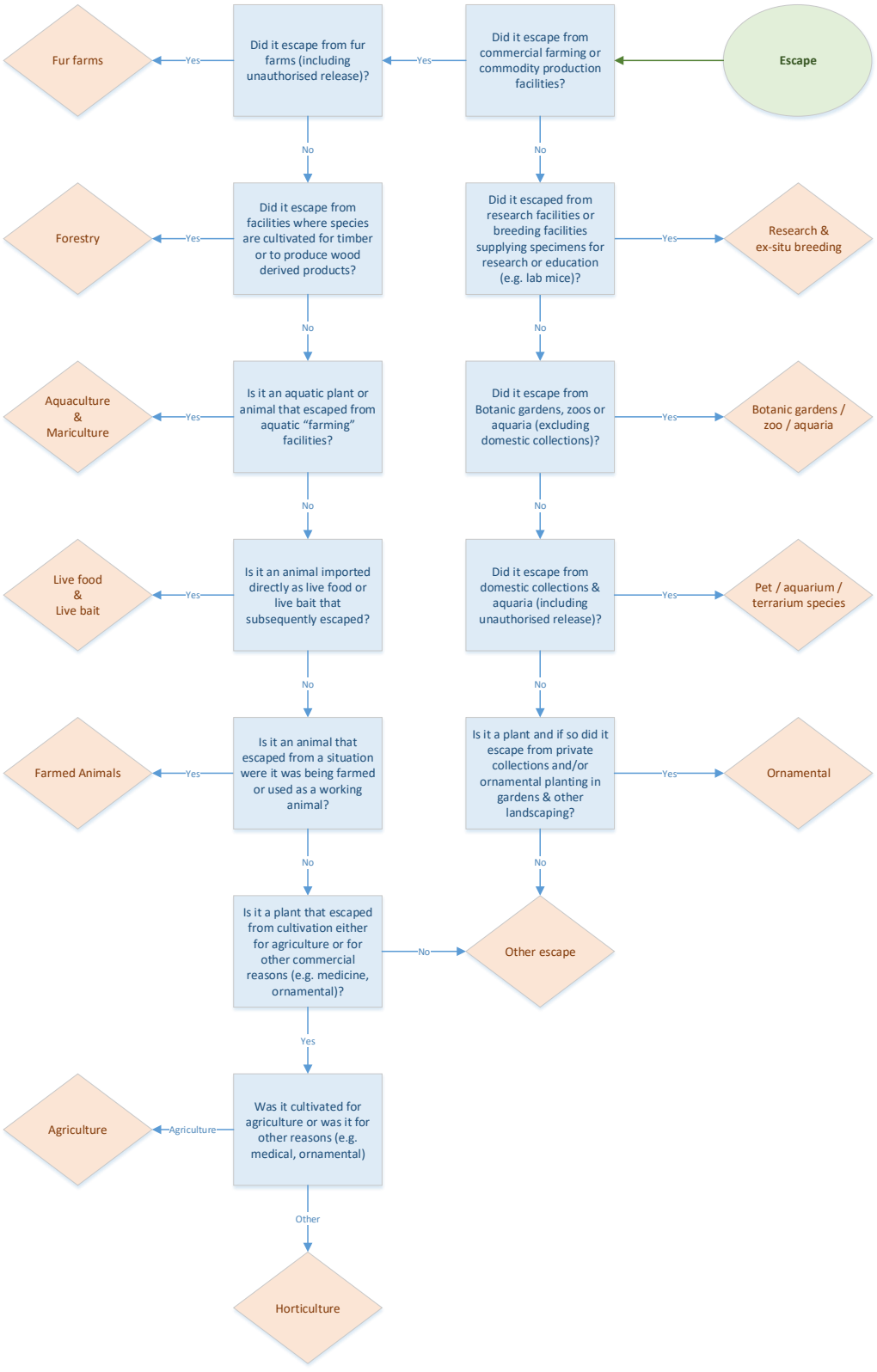


Figure 6 Schematic showing the pathway subcategories within the **Escape from confinement** category and outlining the decision process for assigning species to these pathways. To use this schematic, begin at green oval for the category and proceed through the questions in the blue boxes by following the arrows with the appropriate answers until reaching a subcategory (red diamond). It is important to note that for species can be arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

2.1 Agriculture (including Biofuel feedstocks)

Species that have escaped from confinement or controlled environments where they were cultivated for agricultural reasons, including the production of bioenergy from agricultural crops/commodities, and excluding animals.

Description

Productive agricultural species, and species that provide locally in-demand foodstuffs are frequently planted or farmed outside their native range. This has been a fundamental pathway in the history of human kind, and shaped the socio-economic assets of civilization across the centuries (see Crosby 1986, Diamond 1997). Whilst introduced into a relatively confined and/or controlled agricultural environment, dispersal of seeds, fragments or individuals from this initial point of introduction has seen many species enter new ecosystems around the world. In addition to traditional agriculture crops & products this category explicitly includes species cultivated as bioenergy or biofuel feedstocks.

The **Agriculture** pathway in this categorisation scheme includes plants, algae, fungi and other microbial species farmed in terrestrial environments to produce food and other agricultural crops except for species cultivated primarily to produce wood/timber which are assigned their own specific pathway that takes precedence, **Forestry**. The **Agriculture** pathway does, however, include tree species cultivated in controlled environments to produce food and resources other than wood/timber, for example fruit trees in orchards. The **Agriculture** pathway also includes fungal and other microbial species that are cultivated to produce food and/or resources such as fungi cultivated to produce mushrooms, fungi & micro-organisms used to produce myco/single-cell proteins (e.g. meat substitutes), or yeasts. As mentioned above the **Agriculture** pathway in the current scheme exclude any terrestrial animals that are farmed or used as working animals, as these have their own specific **Farmed animals** pathway. Similarly the **Agriculture** pathway also excludes any aquatic species that are farmed or cultivated as these too have their own specific **Aquaculture / mariculture** pathway.

Similar or Related pathways

This pathway is related to the **Aquaculture / mariculture** and **Farmed animals** pathways in that all three of these pathways cover farming, specifically growing crops and raising livestock. The distinction between the pathways is that **Agriculture** pathway deals with all plants, algae, fungi and microbial species farmed terrestrially; the **Aquaculture / mariculture** pathways deals with plants & animals (namely fish and invertebrates) cultivated or farmed in marine or freshwater environments; and the **Farmed animals** pathway deals with all animals (excluding fish and aquatic invertebrates) farmed for food, to produce products or kept as working animals.

The introduction of pollinating fauna, e.g. bees or other insects, to agricultural systems to improve pollination of crops come under the **Farmed animals** pathway rather than **Agriculture**, as the latter is specific to plants, fungi, algae and microbial species. The pollinators are effectively working animals performing a service on demand and additionally in the case of honeybees, *Apis mellifera*, they are also providing commercial products e.g. honey, wax and royal jelly.

There is also potential for overlap and confusion between the **Agriculture** pathway and the **Release for use** pathway where species are intentionally and directly introduced to a region to be successively exploited for a number of specific uses (such as production of food, crops). The distinction between these pathways is that in the **Agriculture** pathway the species are introduced to confined, controlled or modified environment (e.g. arable fields, glasshouses, orchards, etc.) where the species are cultivated, maintained, and managed but ultimately from which some individuals or propagules escaped (unintentionally) into the (semi)natural environment. In contrast in the **Release for use** pathway the species are released intentionally and directly into the (semi)natural environments and are often left to their own devices to grow and spread with minimal human intervention until suitable for harvesting or collection.

The **Agriculture** pathway may also be confused or overlap with the **Horticulture** pathway as they both involve the commercial cultivation of plants, however the key distinction between them is if that the **Agriculture** pathway deals with the commercial cultivation of plants to produce food and agricultural commodities (e.g. cotton, hemp, plant based oils, etc.) or biofuel, while the **Horticulture** pathway deals with the commercial cultivation of plants for other purposes (e.g. Cut/decorative flowers, Medicine, plant wholes for domestic market, etc.).

Examples

Bamboos (*Bambusa* spp.) have been widely cultivated across tropical and temperate regions of the world for a range of uses including as food and construction material. It invades forests and produces impenetrable clumps

Giant reed (*Arundo donax*) is considered a valuable, very fast-growing crop that is being promoted for the production of fuel, fibres and pulp. It threatens riparian habitats in its invade range such as Mexico.

African oil palm (*Elaeis guineensis*) is a major source of oil for human food use and industrial use. It has been widely planted pan-tropically but it has escape cultivation in some regions.

2.2 Aquaculture / mariculture

Species that have escaped from confinement or controlled situations in either freshwater or marine environments to produce food or other agricultural type products including bioenergy products

Description

This pathway refers to alien species introduced as a consequence of escapes from the confined or controlled situations in aquatics environments (freshwater & marine) in which they are cultivated or farmed for the production of food, for human or animal consumption, or other agriculture type products. This pathway covers any aquatic species of fungi algae, plants or animals (namely fish and invertebrates) that are farmed or cultivated to produce food or products. The cultivation or farming can be in completely artificial environments (e.g. tanks, artificial ponds, fishing lakes) or it can be in (semi-) natural environments where effective measure to prevent the escape of individuals are in place (e.g. cages, fish farming

nets). As with all **Escape from confinement** pathways there is typically a notable degree of husbandry involved in the cultivation or farming of the species.

Similar or Related pathways

This pathway is similar to and can be confused with the **Fishery in the wild** pathway as both can cover the introduction of aquatic species (e.g. fish and invertebrates) introduced into either the marine or freshwater environment to produce food or products. The distinguishing difference between the two categories is that in the **Aquaculture / mariculture** pathway the introduction of a species is the consequence of accidental escapes from a confined or controlled environments where they are initially introduced (and where they are typically cared for, cultivated or farmed) to produce food and other products. In contrast, the **Fishing in the wild** pathway covers situations where aquatic species (also in this case fish and invertebrates) are intentionally and directly released into (semi)natural watercourses or waterbodies, where they are free to move through the whole system, until ready to be fished or harvested (but often receive little to no care, instead are left to fend for themselves, between release and catching/harvesting).

This pathway is related to the **Agriculture** and **Farmed animals** pathways in that all three of these pathways cover farming, specifically growing crops and raising livestock. The distinction between the pathways is that **Agriculture** pathway deals with all plant, algae, fungi and microbial species farmed terrestrially; the **Aquaculture / mariculture** pathways deals with plants & animals (namely fish and invertebrates) cultivated or farmed in aquatics marine or freshwater environments; and the **Farmed animals** pathway deals with all terrestrial animals farmed for food, to produce products or kept as working animals.

Examples

The red swamp crayfish (*Procambarus clarkii*) is a native to North America introduced mainly for aquaculture into several countries on all continents except Antarctica and Australia.

Atlantic salmon (*Salmo salar*), native to the Atlantic, has been introduced around the world. It is a popular food fish but it has negative impacts on native fish populations. Transmission of disease and hybridization with wild populations are of particular concern.

Signal crayfish (*Pacifasticus leniusculus*), native to North America, has been widely introduced around the world for aquaculture.

2.3 Botanical garden / Zoos & Aquaria (excluding domestic aquaria)

Species that have escaped from confinement and that were kept for public display, public education or conservation breeding programmes

Description

This subcategory refers to escapes from facilities such as zoological and botanical gardens where wild animals and plants are confined within enclosures, displayed to the public, and in which they may also breed or be cultivated (e.g. the definition of zoos of the EC Zoo Directive 1999/22/EC is that “zoos mean all permanent establishments where animals of wild

species are kept for exhibition to the public for 7 or more days a year"). Zoological and botanical gardens have a long history, and are the evolution of the simple collections of ancient times. Botanical gardens, zoos and aquaria have long provided the opportunity to show people a selection of species from around the world and more recently for purposes of scientific research, conservation, display and education. For as long as botanical gardens, zoos, or public aquaria have existed there have been escapes. Although the containment facilities and protocols in many modern zoos, aquaria and botanical should prevent escapes they may still happen, e.g. because of damage to boundaries, and through waterways - for instance from an aquarium into rivers, lakes and sea – following clearing operations through the drainage of water, sewage lines, filtration systems or any other breach. This is particularly true under extreme or unusual conditions such as extreme weather events (snow storm, flooding, fire), financial hardships, and social unrest or wars.

This category covers any floral or faunal collections which are routinely displayed to the public ranging from large national botanical gardens, zoos and aquaria down to smaller roadside attractions & gardens (zoos, by definition, display at least a portion of this collection to the public for at least a significant part of the year). This pathway does however cover breeding, conservation or research facilities owned or operated by these organisations that may not be open to the public or on show and that may not even be located in the same location as the main botanical gardens, zoo or aquaria.

The great diversity of facilities and specialized institutions characterised by analogous roles and as such collectively designated as "zoos" greatly vary with respect to the types of animals they exhibit, and this may affect the attribution of the correct category to an alien species pathway. For example zoos can range from general to specialised collections, in which case they might be named after the relevant specialities, e.g. primate zoos, desert zoos, safari parks, bird parks, waterfowl parks, wild fowl reserves, parrot gardens, reptile zoos, insect zoos, butterfly houses, insectaria, vivaria, aquaria, dolphinaria, oceanaria, marine zoos, sea mammal parks, etc. Any other "private collections" such as those presented in circuses, pet shops and any other establishment which does not comply with the definition of zoo, aquaria and botanical garden (as well as rescue centres) should be considered in the subcategory **Other escape from confinement**.

In addition to true escapes from collections such as zoos, botanical gardens and aquaria this category also includes 'facilitated escapes' where species were assisted in their escape and/or released from captivity illegally and without authorisation. It may seem counterintuitive to assign animals that have been released into the wild to an **Escape** type pathway however botanical gardens, zoos or aquaria are the ultimate reason they were in the region and therefore this is the pathway they should be assigned to.

Similar or Related pathways

This pathway shares many similarities and to some extent overlaps with the **Pet / aquarium / terrarium** and **Ornamental purpose other than Horticulture** pathways. The key difference between them is that in the **Botanical gardens / zoo / aquaria** pathway the species in the collection are typically on display to the public (e.g. the definition of zoos of the EC Zoo Directive 1999/22/EC is that "zoos mean all permanent establishments where animals of wild species are kept for exhibition to the public for 7 or more days a year"). Conversely in the **Pet / aquarium / terrarium** and **Ornamental purpose other than Horticulture** pathways the

species in the collection are not typically on display to the public and are often kept by individuals, or small groups, for their own enjoyment, entertainment, companionship, and/or for commercial reasons (e.g. breeding/cultivation for sale to other collectors).

Some confusion may be expected with the **Farmed animals** pathway, whose focus is on animals raised for the primary purpose of them being (commercially) exploited for their meat or other parts and products, in situations where the animals are also on display to the (e.g. in the case of agrotourism or similar establishments). In these cases however the correct pathway will depend upon the primary focus of the establishment, with establishments that primarily focus upon the farming of animals being belonging to the **Farmed animals** pathway, while establishments where the primary focus is upon the display of farm animals belonging to the **Botanic gardens / zoo / aquaria** pathway. A similar situation can also exists for the **Agriculture** pathway, with some establishments (historic farms and other educational farms) focusing on displaying farming practices (historic and/or current) to the public.

There might be some overlap/confusion with the **Research and *ex-situ* breeding** pathway, particularly as Botanical gardens, zoo or aquaria typically run breeding programs and conduct research. This distinction is that **Research and *ex-situ* breeding** pathway is focused on the keeping and/or breeding of animals for use in scientific/medical research conducted in universities, research labs, etc., or for use in science education in universities, colleges, or schools, whereas the **Botanical garden / zoo / aquaria** pathway is refers to flora/fauna from botanic gardens, zoos or aquaria. Additionally, the animals or plants in the **Research and *ex-situ* breeding** pathway are not typically on display to the public prior to escape which is in direct contrast to the **Botanical garden / zoo / aquaria** pathway where this is one of the main reasons for keeping them in captivity.

Examples

Among mammals, the presence of the grey squirrel (*Sciurus carolinenisis*) in Edinburgh and of the red-necked wallaby (*Macropus rufogriseus*) in Derbyshire seems due to the deliberate release of a few animals from a nearby zoo in the beginning of 20th century.

Also, there is the case of a feral population of Siberian chipmunks (*Tamias sibiricus*) in an urban park in the Netherlands, originated in 1972 from a group of chipmunks left behind after the removal of a small zoo.

The African sacred ibis (*Threskiornis aethiopicus*) has escaped from zoological parks in many countries. Surprisingly there are also records of marine mammals introduced from coastal dolphinaria and oceanaria which do not adequately prevent escapes of captive animals into the sea.

Another example of “escape” from a zoological facility is the tropical alga (*Caulerpa taxifolia*): in 1984 a genetically altered type of this seaweed was unintentionally introduced into the Mediterranean Sea possibly with aquaria outflow by a public aquarium in Monaco (for a short review see Scalera et al. 2012).

2.4 Pet / aquarium / terrarium species (including live food for such species)

Species that have escaped confinement or controlled environments where they were kept by private collectors or hobbyists for recreation, enjoyment, companionship and/or trading

Description

For centuries private collectors have been keeping non-native or exotic species as a hobby for companionship and/or for trading with other collectors or hobbyists. Inevitably escapes can happen and when they do some of these species have the potential to survive, establish and become invasive. The importance of the international trade in live animals as pets, home aquaria as an introduction pathway has increased over recent decades with the associated ease of purchasing and exchanging organisms via the internet. This pathway applies to the focal species of the trade, while species associated with the species (e.g. parasites & pathogens, contaminants, stowaways) shall be categorised as the **Parasite on animals** pathway within the **Contaminant on animals** pathway category. The category applies to any and all animal species kept in private collections of wildlife, e.g. by private collectors or hobbyists, not just to the typical vertebrate pet species. It also includes any species kept as live food (e.g. mealworms, locusts, crickets, fruit flies, etc.) for the species kept as pets (but not the relevant contaminants, which have to be considered under the relevant **Transport** related category). It also covers species kept and bred by private collectors or hobbyists for sale or trading with other private collectors or hobbyists. In addition this pathway includes aquarium and terrarium flora as well as other species (including algae, fungi, etc) specifically kept in relation to the aquarium and terrarium trade, which have escaped independently or through 'facilitated escapes' by irresponsible owners, e.g. because of dumping, incorrect disposal of waste, damage to facilities, and through waterways - for instance from an aquarium into rivers, lakes and sea – following clearing operations through the drainage of water, sewage lines, filtration systems or any other breach.

As explicitly stated in the CBD (2014a) document, this may include accidental or irresponsible release of live organisms from confinement, hence in addition to true escapes this category also includes situations where animals are kept in facilities not sufficiently safe to prevent them to escape in the wild, or may even be actively released by irresponsible owners. The dumping or release of unwanted exotic species by owner's or collector's is a particularly common problem with exotic or aquatic species that reach large sizes or have special requirements as naive owners may not appreciate their potential size or requirements when purchasing them as they are commonly sold as juvenile or immature specimens and difficult to care for or rehome as adults (e.g. Pythons and other large constrictors, several fish species such as red-tail catfish, Arapaima, Arowana, etc.).

Similar or Related pathways

The **Pet / aquarium / terrarium species** pathway may be confused with the **Other intentional release** pathway in situations where pet owners or hobbyists have allowed fauna to escape or have actively released the species into the wild. However, as mentioned in the description above these situations are considered 'facilitated' escapes and should still be assigned to the **Pet / aquarium / terrarium species** pathway.

As animals that are kept as pets or in private collections are often selected or kept due to their looks they can be considered as ornamental and therefore there may be confusion between the

current pathway and the **Ornamental purpose other than horticulture** pathway. In the current classification however the **Ornamental purpose other than horticulture** only deals with flora (including algae, fungi, etc.). In general the **Pet / aquarium / terrarium species** pathway is focused mainly on fauna, however it does include aquatic flora kept by aquarists for the reason that the aquarium trade covers the trade in both aquatic fauna and also flora. Any other flora kept by pet owners, collectors of fauna, that are not in aquaria/ponds (e.g. as well as plants used in terraria) are not included in this pathway as they are typically traded separately from the fauna, and therefore fall under the **Ornamental purpose other than horticulture.**

This subcategory shares several similarities and to some extent overlaps with the **Botanical gardens / zoo / aquaria** pathway. The key difference between them is that in the **Botanical gardens / zoo / aquaria** pathway the species in the collection are typically on display to the public (e.g. the definition of zoos of the EC Zoo Directive 1999/22/EC is that "zoos mean all permanent establishments where animals of wild species are kept for exhibition to the public for 7 or more days a year"). Conversely in the **Pet / aquarium / terrarium** the species in the collection are not typically on display and are often kept by individuals, or small groups, for their own enjoyment, entertainment, companionship, and/or for commercial reasons (e.g. breeding/cultivation for sale to other collectors).

The **Pet / aquarium / terrarium species** and **live food and live bait** pathways may also be confused due to the reference to live food in both of their descriptions. The **Pet / aquarium / terrarium species** pathway will apply to all species kept as pets and/or any species used as live food (e.g. mealworms, locusts, crickets, fruit flies, etc.) for the species kept as pets. Any other situations covering live food, such as the important of live foods for human consumption (e.g. lobsters, snails, etc.), or live bait should be categorised under **Live food and live bait** pathway.

Examples

The Common slider (*Trachemys scripta*) is a native to North America currently that has been introduced into many regions around the word (such as Spain, France, Italy, South East & Central Asia, the Caribbean, etc.). This species is one of the most commonly traded reptiles in the pet trade and in many regions the introductions are via the escape or release of pets (the species is known to be traded for human consumption, particularly in Asia).

Red lionfish (*Pterois volitans*) is a native to the Indo-Pacific and has been introduced to the Atlantic coasts of the USA and Caribbean, with the first record in the Florida in the 1990s, spreading into the Caribbean by mid 2000s. The species is a commonly traded species in the marine aquarium trade and the introduction of the species to USA is suspected to be the result of the release of pets.

The Burmese python (*Python molorus bivittatus*) is a native to Asia but has been introduced to Florida and Puerto Rico. The species was first recorded in the Everglades national park in the 1980s. The exact source of the individuals that established the population is not conclusively known but is thought to be a combination of the release of pet that have grown to large or are no longer wanted and also escapes from a breeding facility that was destroyed during hurricane Andrew in 1992 (Florida Fish and Wildlife Conservation Commission website c1990-2018).

The Rose-ringed parakeet (*Psittacula krameri*) is a native to Africa and Asia that has been introduced to many regions around the world, such as many countries in Europe, United States, Hong Kong. The species is a highly traded bird in the pet trade, particularly in the 1960s and 1970s and introductions are thought to have resulted from escapes from private collections. Once in a region the species has been shown to be capable of spreading via natural dispersal.

2.5 Farmed animals (including animals left under limited control)

Species that have escaped from confinement where they were kept with the primary purpose to provide food, resources and/or as working animals

Description

Many species of fauna have been transported to new parts of the world to be farmed to produce food for human or animal consumption, provide resource (such as wool, leather, etc.) or to be used as working animals. This subcategory deals with all animals farmed for these purposes in terrestrial environments. Typical these animals are kept in confined or controlled environments and managed by humans. However in some cases such animals are raised in the (semi)natural environment where they are under limited control, and receive less intensive care and management. Often the species being farmed are from a restricted suite of species that have had a long association with humans and history of domestication. These domesticated species have been introduced to most regions and are associated with human colonisation and settlement. This pathway also includes the introduction of less familiar species that are found to be productive or useful for the purposes noted above, specifically the production of food, resources and/or for use as working animals. This category will also include farming of animals to produce bioenergy (e.g. biogas).

In addition to true escapes from farming situations this pathway also includes 'facilitated escapes' of species helped to escape and/or released illegally and without authorisation from farms or the likes. It also covers situations where farmers/landowners release livestock if and when they are unable or unwilling to look after them any longer.

This pathway does not include situations where species are being farmed to provide fur, to be displayed to the public, or the species being farmed are aquatic species as these are covered by other more appropriate pathways which takes precedence such as, respectively, **Fur farms, Botanical garden / Zoos & Aquaria (excluding domestic aquaria)**, and **Aquaculture / mariculture.**

Similar or Related pathways

This pathway is related to the **Agriculture** and **Aquaculture / mariculture** pathways in that all three of these pathways cover farming, specifically growing crops and raising livestock. The distinction between the pathways is that **Agriculture** pathway deals with all plant, algae, fungi and microbial species farmed terrestrially; the **Aquaculture / mariculture** pathways deals with plants & animals cultivated or farmed in aquatics marine or freshwater environments; and the **Farmed animals** pathway deals with all animals farmed for food in terrestrial environments, to produce food, products or kept as working animals.

There is also the possibility of confusion between the **Farmed animals** pathway and several pathways within the **Release in nature** category, specifically the **Hunting in wild**, **Fishery**

in the wild, and **Release in nature for use** pathways. The distinction between the current pathway and the three **Release in nature** pathways mentioned is that in the **Farmed animals** pathway the species are introduced to, and escape from, confined or controlled environments; e.g. cages, pens, fenced fields, etc. where they receive husbandry. In contrast, in the **Hunting**, **Fishery in the wild** and **Release in nature for use** pathways they are released intentionally and directly into the (semi)natural environment and typically left to look after themselves prior to be captured, used or harvested. An additional distinction with the **Fishery in the wild (including game fishing)** pathway is that the **Farmed animals** pathway deals with terrestrial species while the later deals with aquatic species.

There is overlap between the **Farmed animals** pathway and the **Fur farms** pathway due to the fact that they both deal with animals farmed for exploitation purposes. However, the latter is solely focused on animals farmed primarily to produce furs and therefore should be used in preference of the former in these situations.

There is a major risk of confusion with the **Pet / aquarium / terrarium species**, e.g. in case of animals farmed specifically for being commercially exploited for the pet trade. However any escape from such farms should be considered as belonging to the subcategory **Farmed animals**. Otherwise, should the species escape as a consequence of mismanagement from the final users, the pet owners and hobbyist in private collections, then the correct subcategory would be **Pet/aquarium/terrarium species**.

Examples

Dromedary camels (*Camelus dromedarius*), native to Asia and Africa, have established feral populations following introduction into Australia.

Goats (*Capra hircus*) were domesticated more than 10,000 years ago in Western Iran. They have been introduced worldwide but are particularly problematic on island ecosystems where they alter plant communities through overgrazing.

2.6 Forestry (including reforestation)

Species that have escaped from controlled or confined environments where they are cultivated and managed for forestry and/or to produce wood

Description

Commercial timber operations are a significant worldwide contributor to the spread of alien species of tree. Planted forests comprise trees established through planting and/or through deliberate seeding of native or alien species. In most cases, alien trees are selected for their adaptability to many habitats, including harsh sites, as well as rapid growth – both features that are shared with weedy species (Brundu and Richardson 2015).

Tree species that have specific, required properties or that will produce a valuable resource are planted globally outside their native range to provide for commercial forestry operations. Conifers are the predominant group of trees that are utilized for these operations and are capable to benefit for their reproduction of effective wind dispersal and can readily establish viable populations beyond the forestry plantation.

Similar or Related pathways

There is overlap between the **Forestry** and **Erosion control/ dune stabilization** pathways as they both cover routes by which trees may have been introduced. The main differences between the two is the primary reason for their introduction and the environment into which they are introduced. In the **Forestry** pathway they are typically introduced into controlled or managed environments in which they are cultivated and managed to produce timber or wood. In the **Erosion control/ dune stabilization** pathway they are typically introduced into (semi)natural environments to act as barriers or control aspects of the environment and not typically used to produce wood, timber or other products. Similarly, confusion may also be anticipated with the subcategories of **Introduction for conservation purposes or wildlife management**, and **Landscape / flora / fauna "improvement" in the wild**. However, in these cases also, the primary purpose is not on wood production.

There might be some subtle overlap/confusion with the subcategory **Agriculture**, as both may entail the planting of trees, although in this case the primary purpose is to produce food and other agricultural crops, and not the direct exploitation of wood and timber.

Examples

The Douglas fir (*Pseudotsuga menziesii*) is a conifer introduced for timber production from North America to Europe more than 150 years ago, and is now the most economically-important alien tree species in European forests (Brundu and Richardson 2015).

Prosopis species are small trees native to Mexico, Central and northern South America. Some *Prosopis* spp. were widely introduced and planted as fuel and fodder species, but are now considered noxious weeds. For example *P. juliflora* is problematic in many African countries notably Kenya, Ethiopia and Sudan; in Asian countries such as Pakistan and India; and, also in Australia and South Africa.

2.7 Fur farms

Species that have escaped from captivity or controlled environments where they were bred to produce fur

Description

Historically the pelts used to make fur clothes and accessories came from animals hunted in the wild. In the late 1800s demand for fur increased dramatically due primarily due to fur being promoted by the fashion industry and being seen as a luxury item. This increase in demand, particularly for 'high-quality' fur, gave rise to the practice of farming of animals primarily for fur production. The species typically farmed were those that were prized for their fur and/or those that were relatively easily farmed, e.g. Mink, Chinchilla, Fox, Rabbit, etc. regardless of their native range, which may be far from the location of the farms. Animals escaped the relevant establishments in a variety of ways, leading to the introduction of these species into new regions outside their native range.

This category also includes ‘facilitated escapes’ where animals being bred for fur were helped to escape and/or released from the captive facilities accidentally due to irresponsible behaviour or mismanagement. For instance, there have been many cases where fur farms were targeted by animal rights groups and the animals being kept set free into the (semi)natural environment. In addition to releases by animal rights groups this category also covers situations in which owners turned the animals free or allowed animals to escape via poor husbandry or even in cases where they are unable or unwilling to look after them any longer.

Similar or Related pathways

The **Fur farms** and the **Hunting** and/or **Release in nature for use** pathways may be confused in situations where species are introduced for the exploitation of their fur. The **Fur farms** pathway should be used if the intent was for the species to be kept, raised and breed in captivity or controlled environments (such as pens or cages) to exploited to produce fur, often on a large or commercial scale. In contrast the other two pathways should be used if the intent was to release the species into the (semi) natural environment, often with the aim of creating a self-sustaining populations, from which it can be hunted. In these **Release into nature** situations if the intent behind the release was for the animals to be hunted for sport, with the fur being primarily used/kept as hunting trophies, then the **Hunting** pathway should be assigned. In contrast if the primary intent was for species to be hunted primarily for its fur, which is being utilised to make clothing/products, then the **Release in nature** for use pathway should be assigned.

Some overlap may also exist between the **Farmed animals** pathway and the **Fur farms** pathway due to the fact that they both deal with the exploitation of “farmed” animals. However, the latter is solely focused on the farming of animals for the primary purpose to produce furs, while the former is more widely focused and deals with the production of food, resources or animals to be used as working animals.

Examples

American mink (*Neovison vison*) is a native range to North America introduced for fur farming in many parts of Europe, where it become very common in the wild as a result of the many escapes and (irresponsible) deliberate releases from farms.

Coypu (*Myocastor coypus*) is a large semi-aquatic rodent, native to South America, has been farmed for its fur. Coypu have escaped from captivity and feral populations are now present in North America, Europe and Asia.

2.8 Horticulture

Species that have escaped from confined or controlled environments where they were commercially cultivated for purposes other than Agriculture, Forestry, or Aquaculture/Mariculture

Description

Horticulture is the science and / or practice of garden cultivation and management particularly for use of plants by humans as food, medicine, aesthetic purposes or for any other

use. Species have been introduced outside their native range for the purposes of horticulture from ancient times. By definition horticulture could apply to almost any cultivation of plants, however having such a broad category in a classification scheme such that presented here would be counterproductive as it would encompass plants being cultivated for a wide variety of reasons. In this classification the scope of the **Horticulture** pathway has been restricted to cover only the large scale/commercial cultivation of plants in a controlled or confinement environment, for any use excluding **Agriculture**, **Forestry**, or **Aquaculture / mariculture** which have each been allocated their own pathway.

The **Horticulture** pathway focuses on plants kept in commercial culturing facilities (nurseries, greenhouses) from where they may accidentally escape due to mismanagement, or during transport to/from locations as part of the nursery trade. A notable exception is relative to the aquarium and terrarium flora as well as other species (including algae, fungi, etc) kept in relation to the aquarium and terrarium trade, which must be considered under the **Pet / aquarium / terrarium species (including live food for such species)**.

Similar or Related pathways

There is a notable overlap between the **Horticulture** and the **Ornamental purpose other than horticulture** pathways as both deal with ornamental or decorative plants. The **Ornamental purpose other than horticulture** pathway applies where escape occurs from landscaped habitats or plant collections. In contrast the **Horticulture** pathway should be applied if plants escape from commercial culturing facilities (nurseries, greenhouses) or during transport to/from the nursery trade.

There is a clear risk of overlap between the **Horticulture** pathway and the **Agriculture**, **Forestry** or the **Aquaculture / mariculture** pathways as each covers the commercial cultivation of plants. Firstly, if the species being cultivated are aquatic, excluding species such as rice which can be grown submersed but do not require it, then they would fall under the **Aquaculture / mariculture** pathway. For terrestrial species if they were being commercially cultivated to produce timber or wood products then they would fall under the **Forestry** pathway while commercial cultivation to produce food or agricultural commodities (e.g. cotton, hemp, oil, bioenergy, etc.) falls under the **Agriculture** pathway leaving the **Horticulture** pathway with all terrestrial plants being cultivated commercial for any other reasons (e.g. cut or decorative flowers, medicine, etc.).

The **Contaminated nursery material** pathway within the **Transport - Contaminant** pathway category may be confused with the **Horticulture** pathway as both deal with nursery material, however the former relates to species unintentionally transported between regions on or with nursery material while the later relates to the escape of the nursery material species itself.

There is some risk of confusion also with the **Ornamental purpose other than horticulture** pathway, for example in case of aquatic plants cultivated specifically for being commercially exploited in connection to the aquarium/terrarium trade. In these cases any escape from the relevant commercial culturing facilities (e.g. nurseries, greenhouses) should be considered as belonging to the subcategory **Horticulture**. Otherwise, should the species escape as a consequence of mismanagement from the final users, aquarium amateurs and hobbyists in

private collections, then the correct subcategory would be **Pet / aquarium / terrarium species** .

Examples

Garden lupin (*Lupinus polyphyllus*) is a perennial herb, native to western North America, and has been introduced to Europe, Australia and New Zealand for ornamental purposes, soil stabilisation and cultivation.

2.9 Ornamental purpose other than horticulture

Species that have escaped from confined or controlled environments where they were introduced for decorative or ornamental reasons excluding commercial horticulture.

Description

The trade in species that provide striking structure and colour, or show traits that make them suitable for landscaping in a variety of forms led to the movement of species around the world to improve or enhance municipal areas or private parks and gardens. In particular this subcategory focuses on species kept in private collections by hobbyists or used in landscaped habitats, e.g. for ornamental or aesthetic purposes, and which may accidentally escape into the (semi)natural environment.

The **Ornamental purpose other than horticulture** pathway only applies to flora and not fauna. Fauna that escaped to the wild from situations where they were kept for their looks should be considered as pertaining to the **Pet / aquarium / terrarium species** pathway.

This category does not include plant species or other organisms specifically kept in in relation to the aquarium and terrarium trade, as they are considered under the **Pet / aquarium / terrarium species** pathway.

Similar or Related pathways

There is notable overlap between the **Ornamental purpose other than horticulture** and the **Horticulture** pathways as both deal with ornamental or decorative plants. The **Horticulture** pathway should be applied if plants escape from commercial culturing facilities (nurseries, greenhouses) or during transport to/from the nursery trade. In contrast the **Ornamental purpose other than horticulture** pathway applies where escape occurs from landscaped habitats or plant collections.

The **Ornamental purpose other than horticulture** pathway could potentially be confused with the **Botanic garden / zoo / aquaria** or **Pet / aquarium / terrarium species** pathways as they are all applied to species kept for looks or ornamental value. The **Ornamental purpose other than horticulture** pathway should only be applied to flora and only to those kept or displayed in private collections, gardens, landscaped areas and planted in municipal areas. In contrast the **Botanic garden / zoo / aquaria** should be used for species kept and displayed in institutions that display to the public e.g. botanic gardens, zoos, or public aquaria. Finally, the **Pet / aquarium / terrarium species** pathway applies to escapes of fauna kept as pets, or by

hobbyists in private collections, or any species being bred or transported for this purpose in addition to any aquatic flora kept or cultivated for use in aquaria or ponds.

The **Ornamental purpose other than horticulture** pathway could also be confused with the **Forestry (including reforestation)** pathway as alien tree species can be used as ornamental species, particularly in landscape or larger gardens, as well as for forestry purposes. The Forestry pathway shall only apply to the commercial cultivation of trees for timber/wood production.

Examples

The Water hyacinth (*Eichhornia crassipes*) is native to the Amazon basin and has been introduced to tropical and subtropical regions around the world as an ornamental plant.

Japanese honeysuckle (*Lonicera japonica*) is considered a major pest in North America, Australia, and New Zealand as well as in many countries in Europe and South America where it has escaped from cultivation.

2.10 Research and ex-situ breeding (in facilities)

Species that have escaped confinement or controlled environments where they were kept and/or bred for use in research

Description

The use of organisms in research laboratories is a potential source of animals and plants which may be introduced in the (semi)natural environment outside their native range. In addition to species used, cultivated or bred for research this category covers situations were species are bred or supplied to be used in education establishments for science education (e.g. dissections, mounted specimens, slides, etc.).

Similar to fur farms, research centres that conduct research using animals have been targeted by animal rights activists aiming at releasing such animals into the wild. These 'facilitated escapes' where the species were helped escape and/or actively released illegally and without authorisation are included in this category. In addition this category will also cover situations in which irresponsible owners/managers have turned the organisms free or allowed animals/plants to escape due to bad practices, poor husbandry or even to situations where they were unable or unwilling to look after them any longer (e.g. financial hardships).

This category does not cover research conducted on organisms kept in zoos, public aquaria or botanical gardens as in these cases the main reason for their presence in captivity was not for being kept or bred for research. Similarly this category will not include individuals kept as part of a conservation breeding program which are typically pertaining to the subcategory **Botanical garden / zoo / aquaria.**

Similar or Related pathways

As the majority of zoos, public aquaria and botanical gardens are involved with and/or conduct scientific research there is the possibility of confusion between the **Botanical gardens / zoo / aquaria** pathway and the **Research & *Ex-situ* breeding** pathway. The **Research & *Ex-situ* breeding** pathway, however should only be used where individuals

have escaped from centres whose primary focus is research or *ex-situ* breeding for research, or science education, and that typically do not have their collections on display to the public.

The reference to breeding in the current pathway may cause confusion between this pathway and all the others in the **Escape from confinement** category which are characterised by the target species being kept in captive facilities for purposes entailing their captive breeding. The current pathway however only applies to the breeding of fauna or flora for the primary purposes of research and/or use in or by education establishments for science education, and which may successively escape into the wild as a consequence of mismanagement.

Examples

The African clawed frog (*Xenopus laevis*) was being used from the 1930s onward in laboratory facilities to conduct human pregnancy tests. Once transported beyond their native range in Southern Africa, African clawed frogs were introduced in the wild in several countries around the world.

Rhesus monkeys (*Macaca mulatta*) were released (1,200 female and 150 male) in 1973 from laboratories to Key Lois (historically known as Loggerhead Key), a 39-ha island in the Florida Keys to develop a breeding colony of Rhesus Macaques for biomedical research. The macaques consumed trees and are reported to have led to the destruction of over 30 acres of Red Mangroves on Key Lois alone.

2.11 Live food and live bait

Species that have escaped from confinement or controlled environments where they were kept and/or transported as live food or live bait (excluding live foods given to pet species).

Description

This pathway focuses on the species that are introduced to be used as live bait or as a live food (for human or animal consumption), with the notable exception of live foods used to feed pet species, as they explicitly belong to the subcategory **Pet / aquarium / terrarium species Pet / aquarium / terrarium species (including live food for such species)** . Species to which this pathway applies are typically brought into a region outside their native range at a stage ready to be consumed or to be directly used as bait, rather than being bred or cultivated in the locations from where they could successively escape (in which case some of the other specific pathway from the **Escape from confinement** category would be more appropriate).

Similar or Related pathways

The **Live food and live bait** pathway may be confused with the **Fishing in the wild** pathway as both can relate to recreational or commercial fishing. The latter, however, would be applied to fish as targets of the activity, while the former applies only to the fishing bait.

The **live food and live bait** and **Pet / aquarium / terrarium species** pathways may also be confused due to the reference to live food in both of their descriptions. The **Pet / aquarium / terrarium species** pathway will apply to all species kept as pets and/or any species used as live food (e.g. mealworms, locusts, crickets, fruit flies, etc.) for the species kept as pets. Any other situations covering live food, such as the transportation of live foods for human

consumption (e.g. lobsters, snails, etc.), or live bait should be categorised under **Live food and live bait** pathway.

Similarly, the **Live food and live bait** pathway may be confused with **Aquaculture / mariculture** or **Farmed animals** pathways where species that are used as live food or live bait are being commercially cultured or farmed. The distinction between these pathways relates to the point at which these species escape and whether they are aquatic or terrestrial. If the species escape at the point of being sold, transported or used as live food or live bait they would be assigned to the **Live food and live bait** category. In contrast, should they escape while being in culture, even if they are only being cultured to be sold as live food or live bait, the **Aquaculture / mariculture** or the **Farmed animals** pathways should be applied.

Examples

The rusty crayfish (*Orconectes virilis*) is native to North America and has spread in many other countries within the USA and Canada outside its native range, mostly due to anglers using the species as fishing bait.

2.12 Other escape from confinement

Species that have escaped from confined or controlled environments where they were introduced for any reasons other than those covered by the other categories.

Description

Given the diverse range of reasons why plants or animals are kept in confinement it is likely that in some instances the reasons will not align with the other pathways within the **Escape from confinement** category. This **Other escape from confinement** is a miscellaneous pathway type that can be applied to species that escape from confined or controlled environments and where the reason for the captivity is not covered by the other more specific pathways in the **Escape from confinement** category.

Circuses, pet shops and any other establishment which does not comply with the definition of zoo, aquaria and botanical garden (as well as rescue centres) should be considered here. Similarly any escape of animals used for religious practices and ceremonies should be considered here (this subcategory should not be confused with the "releases" for religious reasons, which in fact should be considered under the **Other intentional release** within the **Release in nature** pathways).

Similar or Related pathways

No specific similar or related pathways were identified.

3 Transport – Contaminant

Species introduced unintentionally or accidentally through the movement of other organisms or organic materials and products.

Transport–Contaminant refers to the unintentional movement of live organisms as contaminants of a commodity that is intentionally transferred through the movement of people and goods, e.g. as a consequence of travels and trade, and similar activities (examples are development assistance, or emergency relief programmes). This includes pests and diseases of animals and plants, and their parts and derivatives, such as food, seeds, timber and other products of agriculture, forestry, and fisheries as well as contaminants of other products.

Similar or Related pathways

The **Transport - contaminant** pathway, and pathways contained within, can often be confused with the **Transport - stowaway** pathway and its sub-categories. The main source of error can be in the understanding of what is meant by the terms ‘contaminant’ and ‘stowaway’. A contaminant can be described as a species which interacts directly with the commodity. In contrast a stowaway is a species that uses vectors, such as cargo containers, packing materials, equipment or transport vehicles, simply to move between locations opportunistically without interacting with the vector.

The **Transport – contaminant** pathway, and the **Transport – stowaway** pathway, may be confused with the **Release into nature** or **Escape from confinement** pathways. The **Transport – contaminant** and the **Transport - stowaway** pathways however refer to species unintentionally or accidently introduced outside of their native range and as such can be easily distinguished from the **Release in nature** and **Escape from confinement** pathways which refer to species introduced intentionally or deliberately.

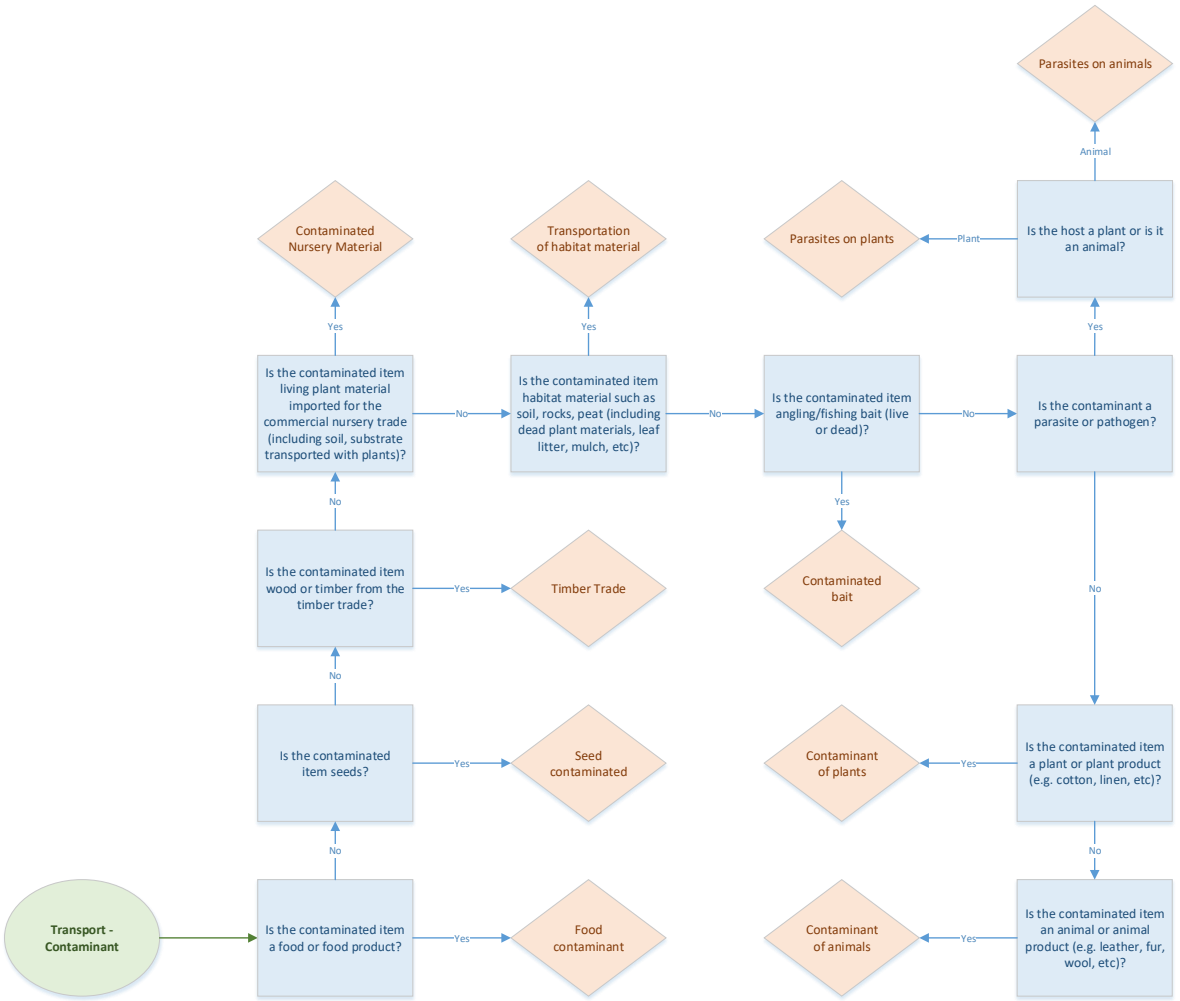


Figure 7 A schematic showing the pathways within the Transport – Stowaway category and the decision process that can be used to determine the appropriate pathway. To use this schematic, begin at green oval for the category and proceed through the questions in the blue boxes by following the arrows with the appropriate answers until reaching a subcategory (red diamond). It is important to note that for species can be arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

3.1 Contaminant nursery material

Species released unintentionally as a contaminant on plants or plant material associated with the commercial nursery trade excluding contaminants transported by seeds or contaminants that are parasites.

Description

Plants used in agriculture, forestry and horticulture are transported from locations across the world as part of the commercial nursery plant trade. The transportation of these plants, is a potential pathway for the unintentional introduction of contaminants such as fungi, animals (either vertebrates or invertebrates) and propagules of other plant species. Included in this subcategory is contaminants included in any habitat materials associated with cultivated or transported plants, such as soil, peat, mulch, leaf litter, etc. around roots or in pots, etc. This is limited to situations where the habitat material is in limited quantities, is included for the sole the purpose of a providing a suitable environment for plants being cultivated or transported, and that the plants are focus of the transport or trade otherwise the **Transportation of habitat material** pathway should be used. Contaminants transported via seed are also excluded from this category, as there is a specific subcategory for this specific stage of plants, namely the **Seed contaminant** pathway. This pathway also excludes any contaminants that are parasites/pathogens which have their own specific pathway, **Parasites on plants**.

Similar or Related pathways

The **Contaminant nursery material** pathway can be confused with the **Contaminant on plants** pathway due to the overlap between these pathways. The **Contaminant nursery material** pathway is effectively a specific subset of the **Contaminant on plants** pathway that focuses upon the commercial nursery trade, which should be used in preference to the broader **Contaminant on plants** pathway in these cases.

This pathway can be confused with the **Transportation of habitat material** pathway, which refers to the movement of contaminants via the movement or trade of habitat materials such as soil, rocks, stones, leaf litter, peat, mulch, etc. Confusion arises out of understanding the distinction between ‘nursery’ material and ‘habitat’ material and to what extent nursery material con encompass habitat materials. Nursery material in this context refers to plants and plant materials (e.g. bulbs, fragments, roots, etc.) as well as any soils, peat, mulch and other habitat materials transported with plants or plant material (e.g. in pots, etc.), but where the plant is the focus of transport, cultivated or traded via the commercial nursery trade. In contrast habitat material refers to the movement or trade, often in large quantities, of habitat materials such as soil, decomposing vegetation (such as leaf litter), mulch, wood chips, rocks, stones etc. in the absence of plants and where these habitat materials are the focus. Contaminants such as fungi, invertebrates (in various life stages), and propagules of other plant species of both nursery and habitat material are a potential vector for alien and invasive taxa to new locations. Although typically associated with organisms such as plants or invertebrates, occasionally vertebrates (e.g. reptiles, amphibians, etc.) are also introduced through these two pathways. In summary it should be noted that **Transportation of habitat material** refers to materials not in association with any specific plant whereas **Contaminated nursery material** includes habitat associated with traded plants.

There is the possibility of confusion with the **Food contaminant** pathway as both could apply to contaminants moved with plants species used for food. The distinction is that the **Contaminant nursery material** pathway refers to contaminants transported by or with plants in the commercial nursery trade, which are then sold to end users, and therefore deals with plants or plant materials prior to them being received by farmers and planted/cultivated to food or crops. In contrast the **Food contaminant** pathway deals with contaminants associated with the food plants, or food/crop products themselves, once planted by farmers.

There is also overlap between the **Contaminant nursery material** and the **Seed contaminant** pathway in situations where contaminants are present in/on seeds being commercial cultivated or traded part of the nursery trade. In these cases however, the **Seed contaminant** pathway is the more specific pathway and should be used in preference to the **Contaminant nursery material** pathway.

Examples

The New Guinea flatworm (*Platydemus manokwari*) is native to New Guinea but has been introduced to several regions across Oceania including Australia, Guam, Palau, Hawaii, Federated States of Micronesia, French Polynesia and Samoa (Justine et al. 2014). In several regions this introduction is thought to have resulted from contaminated soils transported with pot plants, however in some regions (e.g. Guam) this species was intentionally introduced for biocontrol of invasive giant African snails (CABI Invasive Species Compendium 2017).

The flowerpot snake (*Ramphotyphlops braminus*) is native to Africa and Asia but has successfully colonized many subtropical and tropical regions (such southern USA, Mexico, Australia, Hawaiian Islands, Guam, Fiji) through the movement of the soil with potted nursery plants (Kraus 2009).

The ocellated skink (*Chalcides ocellatus*) in Naples (Italy), which seems to have been transported accidentally from Sicily in the roots of citrus trees in 1738 (Kornilios et al. 2010).

3.2 Contaminated bait

Species introduced unintentional as a contaminants in/of bait

Description

Live, frozen or preserved bait, such as fish (e.g. minnows, herrings etc.), worms and other taxa (e.g. insect larvae), are imported and transported at both the global and local level with the purpose to feed or catch fish or invertebrates (e.g. crustacean, cephalopods, molluscs, etc.). These taxa can harbour contaminants, pathogens, and parasites and therefore the storage, use or disposal of bait can be a pathway of introduction for these contaminant species.

This subcategory should include any contaminant on food for animal consumption (including farmed animals, pets, etc.), so to avoid overlap and confusion with the subcategory **Food contaminant (including of live food),** which should be focusing on food aimed at human consumption only.

Similar or Related pathways

There could be confusion with the **Angling / fishing equipment** pathway as both are related to fishing and baits are part of the equipment used by fisherman and anglers. The key distinguishing feature between these two pathways categories is that **Contaminated bait** pathway refers to unintentional movement of species with bait species with which they interact. In the **Angling/fishing equipment** pathway however the species being unintentionally transported are simple stowaways and therefore only temporally associated with equipment there is no ecological relationship or interaction.

There could also be confusion with the **Live food and live bait** pathway within the **Escape** category. The distinguishing feature in this case is that the **Contaminated bait** pathway refers to the unintentional or accidental introduction of contaminant species transported alongside the bait species rather than the bait species themselves, the introduction of which is covered by the **Live food and live bait** pathway. The same considerations apply to the live species kept as food for pets etc. which belong to the category **Pet / aquarium / terrarium species (including live food for such species)**.

Some clear confusion with the subcategory **Food contaminant (including of live food)** exists, which however is characterized by focusing on food aimed at human consumption with the exclusion of fish and marine or freshwater invertebrates.

Examples

The zoospores of the pathogen *Aphanomyces astaci* (causative agent of crayfish plague), the zebra mussel (*Dreissena polymorpha*) and the Asian clam (*Corbicula fluminea*) can be transported via the gastrointestinal tract of fish moved between sites by anglers as live bait fish (Anderson et al. 2014).

Frozen fish used as bait can spread viral hemorrhagic septicemia (VHS) Virus, *Vibrio anguillarum* Bergeman, 1909 (Hine and MacDiarmid, 1997). The freezing processes preserves the viral pathogen and the use of such fish as baits can introduce the pathogens.

3.3 Food contaminant (including of live food)

Taxa introduced unintentionally as a contaminant of food including live food.

Description

Increased trade in food (crop and edible crop products) including live foods (i.e. foods that are either eaten/cooked alive or those that are transported live for processing into food, e.g. animals for meat) is a potential source of unintentional introduction of contaminants including alien species into new locations (e.g. fungal spores and infestations, insects, parasites). This subcategory should be assigned to any species that are contaminants of species or products being transported for the purpose to be used as food for human consumption only, and in the case of plants, should include seeds as well (where the seeds are foods).

Similar or Related pathways

Some confusion may exist with the subcategory **Contaminated bait,** which however refers only to bait (used to feed or catch animals such as fish or invertebrates), and not food aimed at human consumption and animal consumption (including farmed animals, pets, etc.).

There is also risk of confusion with the **Contaminant nursery material, Contaminant on animals, Parasites on animals, Contaminant on plants, Parasites on plants** pathways. However the **Food contaminant** should only be used for contaminants on animal or plant products that are transported to be used as food for human consumption. Therefore any contaminant on organisms transported to be farmed, raised, before being used as food for animals, etc. should be assigned into the relevant pathways listed above (**Contaminant nursery material, Contaminant on animals, Parasites on animals, Contaminant on plants, Parasites on plants**) for their immediate fate, even if they will ultimately be used for food consumption, for instance after further cultivation.

There is possibility of confusion between the **Food contaminant** and **Seed contaminant** pathways as both can apply to seed contaminants, however any seeds destined for human consumption (as seed or seed products such as flour) should be assigned to the **Food contaminant** pathway, while contaminants of seed destined for any other use should be assigned to the **Seed contaminant** pathway.

Examples

The Mediterranean fruit fly (*Ceratitis capitata*) is endemic to sub-Saharan Africa but has been introduced to many regions of the world on imported fruit containing larvae of the fruit fly.

3.4 Contaminant on animals (excluding parasites and species transported by host and vector)

Species introduced unintentionally as contaminants on animals transported through human related activities

Description

Animals are transported by humans across locations and around the world for a variety of purposes, mostly linked to trade, hence in relation to activities such as farming, for display, sport, research, food, or as pets. Soil material on hooves or feet, plant seeds, invertebrates and other contaminants on the body and coats of animals are typical pathways leading to the unintentional introduction of a number of alien species. This sub-category refers to contaminants carried on or in the body of the animals (i.e. transported in the digestive system, such as seeds, fruit, etc.) excluding parasites/pathogens which have their own specific pathway that takes precedence: **Parasites on animals**.

This pathway includes contaminants on dead animals or animal products (e.g. hides/fur, leather, wool, dung, etc.) in addition to contaminants on living animals. The pathway also includes contaminants on material associated with the species and required to ensure its comfort and safety during transport, such as the water in which aquatic species are transported; the substrates (soil, hay, sawdust, coconut fibre, etc.) used in the transport containers; or any food/water supplied for subsistance during travel.

Similar or Related pathways

It is possible that this pathway may be confused with the **Parasites on animals** pathway resulting in parasites and pathogens being assigned to the **Contaminant on animals** pathway or alternative non-parasites/pathogenic species being assigned to the **Parasites on animals** pathway. However, as mentioned above this pathway explicitly excludes parasites/pathogens which should be assigned to the **Parasites on animals** pathway while non-parasitic/pathogenic contaminants should be assigned to the **Contaminant on animals** pathway.

The current pathway may also be confused with the **Food contaminant** pathway as they can both apply to situations in which animals or animal products are responsible for the introduction of alien species. The **Food contaminant** pathway however should only be used where the contaminants are of animals or animals products being transported with the immediate purpose of being used as food for human consumption and not to be farmed, raised in closed facilities, or released in the (semi)natural environment, even if they will be secondarily be used for food consumption.

Animals movement and dispersal throughout their range, including migratory movements of animals such as birds, fish or ungulates, can be a vector of alien contaminant species, e.g. on mud in their feet, or stuck in fur/feathers, however as they move without human assistance, the introduction of species as a contaminant of migratory species should not be assigned to the **Contaminant on animals** pathway, but rather to the **Natural dispersal** pathway.

Examples

Bathurst Burr (*Xanthium spinosum*) is native to South America but has been introduced to many regions around the world (USA, Canada, China, Australia, Europe). In Australia it is a common weed species in pastures, along water courses and around watering holes. It has been observed in Australia that the hooked spines on the fruit (burrs) produced by the plant are a common contaminant of wool and is dispersed on the wool and fleece of animals (Department of Primary Industries, Victoria, 2007).

3.5 Parasites on animals (including species transported by host and vector)

Unintentional introduction of parasitic species transported by a host animal or an animal that acts as a vector

Description

Animal species that are transported between locations have the potential to carry on or in their body a variety of parasitic organisms (such as bacteria, viruses, protozoans, fungi etc.) that are normally associated with the animal's natural habitat. When introduced to novel habitats these parasitic organisms have the potential to become invasive (Roy et al. 2017).

As mentioned above this pathway is not restricted to parasitic species but includes pathogenic organisms.

Similar or Related pathways

There can be some confusion between this pathway and the **Contaminant on animals** pathway as both deal with contaminant species transported by animals, however the **Contaminant on animals** category explicitly excludes parasites and pathogens while these are the exclusive focus of the **Parasite on animals** pathway.

There is also possibility of confusion with the **Food contaminant** pathway which can also cover parasites or pathogens transported via the movement of animals. The **Food contaminant** pathway however deals with contaminants of animals, or animals products, (including parasites & pathogens) that are to be used as food for human consumption (and not farmed, raised in closed facilities, released in the (semi)natural environment, even if they will be secondarily used for food consumption).

In contrast, the **Parasites on animals** pathway excludes contaminants of animals, or animal products, that are to be used as food for human consumption and is restricted to parasitic or pathogenic contaminants.

Similarly, any risk of confusion with the subcategory **Contaminated bait** should be limited by the fact that this category refers to contaminants on animals specifically used as bait to feed or catch fish or invertebrates (additionally, the **Contaminated bait** subcategory covers contaminants on organisms used as food for animal consumption, including farmed animals, pets, etc.).

Examples

The ectoparasitic honey bee mite (*Varroa destructor)* was confined to the Eastern honey bee (*Apis cerana)* but shifted to the Western honey bee (*Apis mellifera)* and subsequently dispersed worldwide with transported honeybees. It is considered a major threat to apiculture.

Aphanomyces astaci, an oomycete and causal agent of crayfish plague, has devastated native crayfish populations in Europe where it arrived more than 150 years ago with imported crayfish from North America (Filipov´a et al. 2013).

The chytrid fungus *Batrachochytrium dendrobatidis*, and the closely related *Batrachochytrium salamandrivorans*, are responsible for the dramatic declines of amphibian species worldwide, and, at least in part, has been transported between countries via the movement of contaminated amphibians for the pet trade and also food trade (Martel et al. 2014).

3.6 Contaminant on plants (excluding parasites and species transported by host and vector)

Species introduced unintentionally as contaminants on plants or plant products transported through human related activities (excluding parasites)

Description

Plants are used in several sectors, such as agriculture, forestry and horticulture, and as such are transported from various locations across the world. Contaminants on these plants or plant

material can be unintentionally introduced to new locations. This pathway excludes parasites/pathogens transported with the plants or plant material.

This pathway also excludes contaminants of plants that are being cultivated/ or traded as part of the commercial nursery trade which has its own specific pathway (**Contaminant nursery material**). This pathway therefore is specific to plants that are not currently part of the commercial nursery trade, for instance plants being transported for non-commercial reasons or plants originally from the commercial nursery trade that have left the trade and been purchased by and used/planted by an end user. This pathway also excludes any contaminants on seeds as these have their own pathway, namely the **Seed contaminant** pathway. Contaminants of timber or wood transported for the timber trade are also not included in this subcategory, as there is a specific pathway **Timber trade**, for contaminants associated with this trade. Similarly, this pathway does not cover contaminants of any plants or plant products being transported for use as food for human consumption unless they will be farmed, cultivated, or released in the (semi) natural environment prior to being used for food consumption (see similar or related pathways for more details).

Similar or Related pathways

There can be confusion between the current pathway and the **Parasites on plants** pathway as both cover situations in which alien species are transported unintentionally through the movement of plants or plant material. The distinction between these pathways is that the **Parasite on plants** pathway will apply to any parasite species while the **Contaminant on plants** pathway will apply to any other species with trophic or abiotic relationships with the plants or plant material being transported.

There is also possibility of confusion with the **Food contaminant** pathway in situations where the plants are food species. The **Food contaminant** pathway however refers to any contaminants on plants or plant products transported to be used immediately as food for human consumption. If on the other hand the species, and it's associated contaminants, is to first be planted, cultivated, or released in the (semi) natural environment, even if ultimately purpose it for it to be used for food consumption then the **Contaminant on plants** pathway will apply

There is overlap between the **Contaminant on plants** and **Seed contaminant** pathways as the latter deals with a specific subset of the former in that both deal with contaminants on plant material, but the latter deals exclusively with seeds. As the **Seed contaminant** pathway is more specific it should be used in preference of the **Contaminant on plants** pathway in situations where the contaminant relates to seeds and **Contaminant on plants** used in the remainder of cases.

The **Contaminant on plants** pathway can also be confused with the **Contaminant nursery material** or **Timber Trade** pathway due to the overlap between these pathways. The **Contaminant nursery material** and **Timber trade** pathways are effectively specific subsets of the **Contaminant on plants** pathway focused upon contaminants on plants in the commercial nursery trade or in wood/timber in the timber trade respectively. The **Contaminant on plants** pathway therefore deals with any contaminants on plants in situations not covered by the more specific contaminant pathways, such as **Contaminant**

nursery material; **Parasites on plants**; **Seed Contaminant**; **Food contaminant**; or **Timber trade** pathways.

Examples

Eggs of the brown marmorated stink bug (*Halyomorpha halys)* were found on leaves and foliage found in containers, during a container survey in New Zealand. The leaves and foliage were themselves contaminants and were a source for the contaminant egg masses (Ministry for Primary Industries, 2012).

King snakes (*Lampropeltis getula)* are frequently accidentally introduced as contaminants on live plant material such as ornamental trees (De Urioste and Mateo 2011) potted plants or old ornamental trees e.g. citrus and olive trees. *Lampropeltis getula* is a fossorial, ground dwelling species, and is not known to climb in trees or other large plants but could be moved along with plants whilst hiding near the stem, in leaf litter or roots.

3.7 Parasites on plants (including species transported by host and vector)

Unintentional introduction of parasitic organisms transported by a host plant or a plant that act as vector

Description

Plant species that are transported across locations have the potential to carry parasitic organisms (such as bacteria, viruses, protozoans, fungi etc.) that are normally associated with the plant's natural habitat. When introduced to novel habitats these parasitic or pathogenic organisms have the potential to become invasive (Roy et al. 2017).

This pathway excludes seeds as there is a specific pathway **Seed contaminant** that should be used in this case. This pathway also excludes contaminants on timber which has its own specific pathway (**Timber trade)**.

Similar or Related pathways

There can be confusion with the **Contaminant on plants** pathway as both deal with species unintentionally transported with plants. The **Contaminant on plants** pathway however explicitly excludes parasitic species, which should instead be assigned to the **Parasites on plants** pathway.

The current pathway may also be confused with **Food contaminant** pathway in situations where parasitic or pathogenic species are transported with plants, or plant products, that are to be used as food for human consumption. In such cases however the **Food contaminant** pathway should take precedence and be assigned, unless they are plants which are to be farmed or cultivated further before being used for food consumption in which case they should be assigned to the **Parasites on plants** pathway.

Similarly the current pathway may be confused with the **Timber trade** pathway in situations where the species are parasites or pathogens of tree species used in the timber trade, or wood and timber itself. In situations where the contaminated product is timber, dead wood, or wood derived products the **Timber trade** pathway should be assigned as it is more specific. In

contrast if the contaminated item is a living specimen (e.g. saplings being transported for forestry) then the **Parasites on plants** pathway should be assigned

Examples

Eucalyptus rust (*Puccina psidii*) has an expanding range and while it can be wind-dispersed over long distances it is also known to have been transported within and between continents through transport of diseased plants. It can remain asymptomatic within plants for more than a month and so can go unnoticed during trade.

Chalara dieback of ash, also known as 'Chalara', ash dieback or Chalara ash dieback, is a disease of ash trees caused by a fungus called *Hymenoscyphus fraxineus*. It has been introduced into many countries through the movement of diseased ash plants.

3.8 Seed contaminant

Species introduced as contaminants of seed with the exception of seed being used for human consumption

Description

This pathway explicitly refers to species contaminating seed shipments. Such contaminants may be either parasites or pathogens of seeds, seeds of species other than the one targeted by the shipment, or species that have a trophic or abiotic relationship with the seed (e.g. seed pests). The global trade in seed for crop, vegetable and flower production, for making ornamental objects such as jewelry and novelty items, for animal consumption and for processing is vast. This pathway includes all contaminants of seeds except for contaminants of seeds being used for human consumption (where the seed, or seed based products, e.g. flour, themselves are being eaten) which should instead be assigned to the **Food contaminant** pathway.

Similar or Related pathways

There is potential for confusion with the **Food contaminant** pathway in the case of contaminants on seed destined for human consumption. If the seed is to be consumed directly, or processed to produce seed products such as flour which will be consumed, then the **Food contaminant** pathway should be assigned. If, however the seed is to be planted and cultivated in order to produce the food or food products then the **Seed contaminant** pathway should be assigned.

Confusion may also arise with the subcategory **Contaminant nursery material**, **Contaminant of plants** or **Parasite of plants pathway** which could also been seen to apply to seed. The **Seed contaminant** pathway should however be used in preference to each of these pathways in situations where the contaminated item is seed

Examples

The spread of Common ragweed (*Ambrosia artemisiifolia*) through commercial bird feed for aviaries and garden feeders has been reported across Europe (Bullock et al. 2012). Additionally, early introductions of Common ragweed (*Ambrosia artemisiifolia*) seed into most invaded countries in Europe are considered as a consequence of the import of

contaminated seed and grain of cereals and other crops (Bullock et al. 2012) and as long as such plant are used for agricultural purposes and not immediacy for human consumption, the example is relevant here and not in the category **Food contaminant (including of live food)**.

Parthenium hysterophorus (congress grass) is perhaps the most noxious weed of urban and rural India. It rapidly colonizes replacing native vegetation but also causes a number of human health problems such as skin allergy, rhinitis and irritation to eyes. It is thought to have been introduced into Australia and India in the 1950s, probably as a contaminant of grain or pasture seeds. The longevity of seeds in soil seed banks, and small and light seeds that are capable of long distance travel via wind, water, birds, vehicles, farm machinery and other animal traffic, have contributed to its introduction worldwide.

3.9 Timber trade

Species unintentionally introduced as contaminants on timber, wood or wood derived products.

Description

Timber is commercially traded across the world for the construction and building industry, as well as in the energy sector. Contaminants on unprocessed lumber including pathogens (such as fungi), can be unintentionally introduced to novel locations where they can spread, invade and have serious negative impacts on tree species in these introduced regions.

This pathway covers contaminants on raw timber, processed wood as well as finished wood, or wood derived products (e.g. wooden furniture, saw dust, fire wood).

Similar or Related pathways

This pathway can be confused with the **Organic packing material** pathway as both categories cover contaminants of wood products. While both the sub-categories refer to timber, the distinguishing feature is that **Timber trade** refers to contaminants in unprocessed timber whereas, **Organic packing material** refers to stowaways in packing material made of organic material, e.g. including wood.

Other elements of confusion may be identified in relation to the subcategory **Transportation of habitat material** which may also include wood and wood derivatives. The **Transportation of habitat material** pathway should be assigned only in situations where wood or raw wood products are to be used for landscaping and/or form an integral part of substrates (e.g. bark chippings, drift wood, bog wood, mulch). The **Timber trade** pathway should be assigned in all other situations where contaminants are being transported with wood or wood-based products.

Some confusion may also arise in the case of overlap with the subcategories of the **Transport – Stowaway** category, as there are cases of introduction of animals, which are introduced as a consequence of **Timber trade**, but actually are moved as stowaway in containers, vehicles etc. associated with the timber trade. In such cases the stowaway pathway appropriate for the actual vector should be assigned (e.g. **Container / bulk** when transported in cargo containers with cargo shipments of timber/wood, or **Machinery / equipment** when transported on/in equipment or machinery used in the timber trade).

There could be confusion with the two subcategories **Contaminant on plants** and the **Parasites on plants**, as they refer to an entire plant or their part (including live trees), but should not include contaminants on timber, or wood derived products, which are moved as a commodity.

Examples

The emerald ash borer (*Agrilus planipennis)* is an East Asian wood-boring beetle that is causing considerable damage to ash (*Fraxinus* spp.) in the USA and Canada. It is mainly introduced through the transport of infested firewood and other wood products.

3.10 Transportation of habitat material (soil, vegetation, wood…)

Species unintentionally introduced as contaminants of habitat material that includes soil, vegetation, wood products such as chips and mulch, straw, etc. when these products are the focus of trade and not simply transported with plants

Description

The transportation of massive quantities of habitat material such as soil, vegetation, wood chips, mulch, straw etc. is a potential source of alien and potentially invasive taxa being introduced as contaminants to new environments. Contaminants include soil microbes, pathogens and fungi etc. Also, contaminants on timber are not included in this subcategory, as there is a specific subcategory **Timber trade**, which include contaminants relevant to this commodity derived from plants specifically.

This pathway should not be used for contaminants in small quantities of habitat material that are transported with plants (e.g. soil or substrates in pots or amongst roots in root balls) as long as the plants are the focus and the substrate is only to ensure or promote the survival of the plant (for details about the difference between "nursery" and "habitat" material, see the description of under **Contaminant nursery material)**. In this situation the **Contaminated nursery material**, **Contaminant on plant** or **Parasite on plants** pathways should be used as appropriate.

Similar or Related pathways

There is potential for confusion with the other pathways that cover contaminants of plants or plant material and can cover contaminants in habitat material such as **Contaminant nursery material, Contaminants on plants,** or **Parasites on plants**. The distinguishing feature here is whether the habitat material is the focus of the transport or trade, often being transported in large quantities, or is it being transported, often in small quantities, along with plants or plant material which are the focus of the transport or trade. If it is the former then the **Transport of habitat material** pathway is appropriate and should be assigned, while in the later situation the relevant plant focus pathway should be assigned (**Contaminant nursery material, Contaminants on plants,** or **Parasites on plants**).

Examples

Lasius neglectus, invasive garden ant, is a recent arrival in Europe from the Middle East, first recorded in Hungary in 1990. It is thought to have been introduced through the movement of potted plants, turf peat and soil from construction in which it forms colonies.

Construction sites are commonly invaded by the Common ragweed (*Ambrosia artemisiifolia*), which suggests translocation of soils and gravels from construction sites in infected areas in Europe (Bullock et al. 2012).

4 Transport- Stowaway

Species introduced into natural environments as accidental stowaways or hitchhikers on a variety of vectors

Description

The **Transport - stowaway** category refers to the unintentional or accidental movement of live organisms as stowaway or hitchhikers, attached to a multitude of means of transport and associated equipment and media. The physical means of transport-stowaway include various transportation methods: ballast water and sediments, biofouling of ships, boats, offshore oil and gas platforms and other water vessels, dredging, angling or fishing equipment, civil aviation, sea, and air containers. Stowaways of any other vehicles and equipment for human activities, in military activities, emergency relief, aid and response, international development assistance, waste dispersal, recreational boating, tourism (e.g., tourists and their luggage) are also included under this pathway**.**

Similar or Related pathways

Transport – stowaway, and **Transport – contaminant**, can be relatively easy distinguished from the other main pathway categories, namely **Release in nature** and **Escape from confinement**. The **Transport- stowaway** and the **Transport- contaminant** pathways can be distinguished from the **Release in nature** or **Escape from confinement** categories by whether the taxa was unintentionally or accidently transported to a new region (as in the case of **Transport-contaminant** and **Transport- stowaway**) or if the taxa was intentionally or deliberately introduced, either into the wild or in a confinement (as in the case of **Release in nature** and **Escape from confinement**).

The **Transport - stowaway** category, and subcategories contained within, can be confused with the **Transport - contaminant** pathway and its sub-categories. However, as a rule of thumb, the easiest way to identify the correct category is to focus on the meaning of the terms ‘stowaway’ vs. ‘contaminant’. A stowaway is a species that uses vectors to move between locations by chance or unknowingly; whereas a contaminant can be described as one which an association to a specific organisms or habitat. For instance an invertebrate species that lays eggs on certain plant species which are transported would be a contaminant of those plant species, however adults of the same invertebrate species happen to enter a cargo container and are transported with then they are a stowaway.

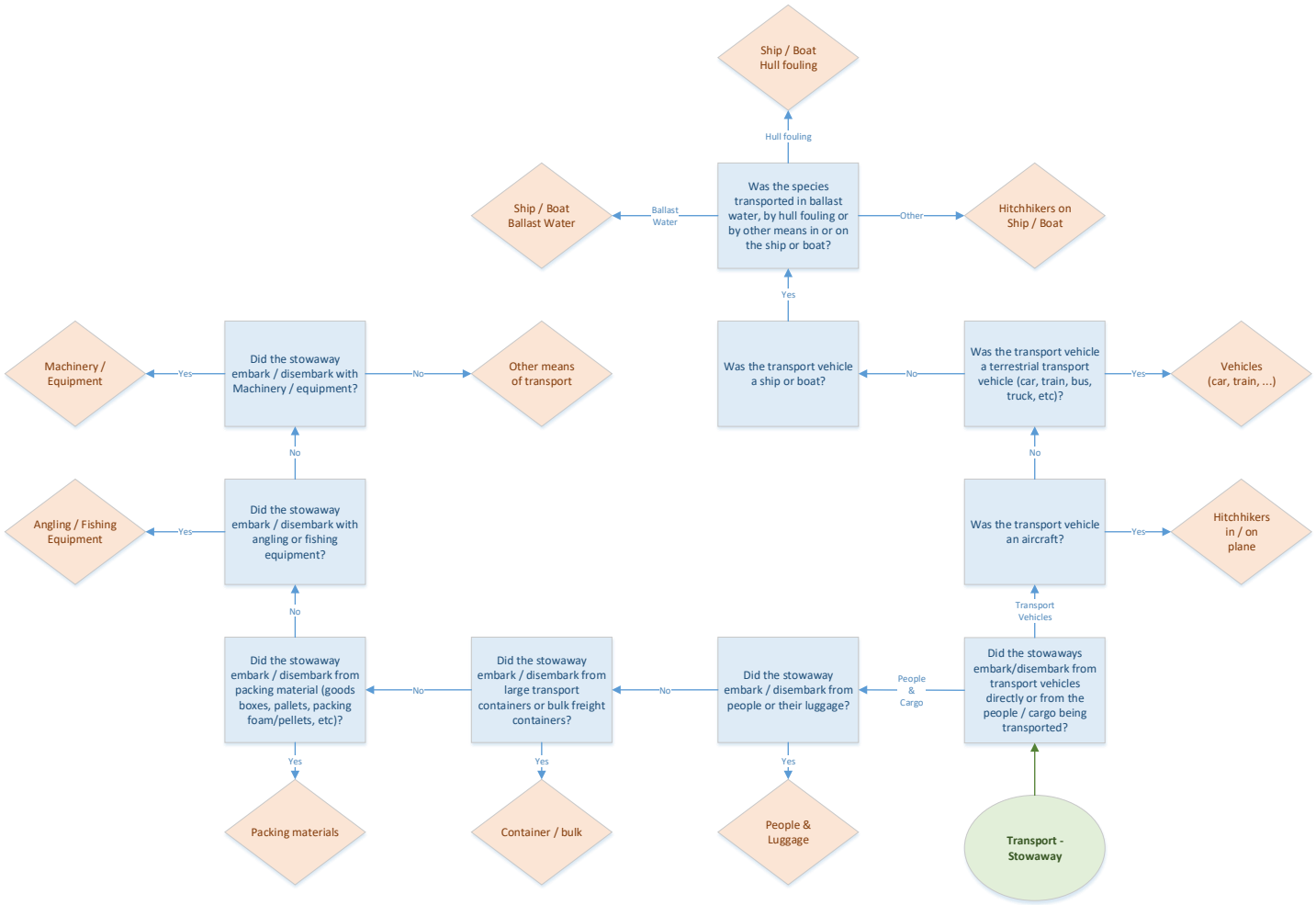


Figure 8 A schematic showing the pathways within the Transport – Stowaway category and the decision process that can be used to determine the appropriate pathway. To use this schematic, begin at green oval for the category and proceed through the questions in the blue boxes by following the arrows with the appropriate answers until reaching a subcategory (red diamond). It is important to note that for species can be arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

4.1 Angling / fishing equipment

Species introduced unintentionally as stowaways on equipment used by recreational anglers or commercial / professional fishermen

Description

Recreational anglers and commercial / professional fishermen can move aquatic species (including aquatic plants, amphibians, fish, invertebrates, algae, and even fungi, viruses and bacteria) as accidental stowaways in or on their equipment when they move from site to site and even across countries. Stowaways on angling/ fishing equipment have the potential to survive for lengthy periods and can be introduced and spread into novel environments. Angling/fishing equipment can include wet equipment, equipment in standing water or those that hold reservoirs of water for example boots, pots, buoys, hooks, lines, sinkers, floats, rods, reels, baits, lures, spears, nets, gaffs, traps, waders and tackle boxes. Angling/fishing equipment will also cover equipment used in projectile or spear fishing.

Similar or Related pathways

Three other sub-categories of pathways, two of which under the **Transport - stowaway** category (namely **Ship/boat ballast water** and **Ship/boat hull-fouling**) and one under the **Transport- contaminant** pathway (namely **Contaminated bait**), can be confused with the **Angling/fishing equipment** pathway.

The **Angling/fishing equipment** pathway is distinguished from **Hitchhikers on Ship/boat**, **Ship/boat ballast water** and **Ship/boat hull-fouling** pathways by whether the stowaways were transported on/in equipment used by that fisherman (both commercial and recreational) or in/on the boats (e.g. commercial fishing vessels, kayaks, canoes, and inflatable boats, etc) they use. Any species transported in or on the ships/boats used by fisherman should be assigned to the appropriate boat stowaway pathway depending on if it was transported via ballast water, hull-fouling or any other location. Species transported as stowaways on any other fishing equipment should be assigned to the **Angling/fishing equipment** pathway.

There is possibility for confusion between the **Angling / fishing equipment** pathway and the **Contaminated bait** pathway. The key distinctions between the two pathways are that the **Contaminated bait** pathway deals only with bait (in the regard to angling or fishing) and the contaminant species has an association with the bait species. In contrast in the **Angling / fishing equipment** pathway the relationship between the stowaway and vector is coincidental and is not restricted to fishing bait but rather any equipment or items used in fishing.

Examples

In Europe both the pathogen *Aphanomyces astaci* (causative agent of crayfish plague) and the killer shrimp (*Dikerogammarus villosus*) can be transported on wet angling gear (Anderson et al. 2014).

4.2 Container/bulk

Species introduced as accidental stowaways on containers, bulk freight, airfreight, rail freight etc. (e.g. shipping containers, other cargo in boxes)

Description

The transportation of freight (bulk cargo, merchandize and commodities) is handled by ships, boats, barges, air planes, train, vans and trucks. Accidental stowaways (including insects, reptiles, mammals and even birds) hidden in or on shipping containers can be transported between locations and countries by land, sea or air and introduced to new environments.

Similar or Related pathways

There can be confusion between the **Container/bulk** pathway and the other pathways within the **Transport-stowaway** category that refer to transport that could involve the movement of bulk cargo/containers such as **Hitchhikers in or on airplane, Hitchhikers on ship/boat, Other means of transport**. The distinguishing feature is the point at which stowaway species entered and/or existed the method of travel. For example, a species may be transported by entering a shipping container, which is subsequently loaded onto a ship with other containers and before being transported to new region and released when the container was opened. In this case the pathway would be **Container / bulk,** and not **Hitchhikers on ship/boat,** as the species interacted (embarked and disembarked) from the container rather than the ship, even though the container, and it's stowaway, were ultimately transported via ship. Therefore the **Container/bulk** pathway refers to stowaways transported in or on the cargo containers or bulk cargo units themselves.

Examples

The delicate skink (*Lampropholis delicata*), native to Eastern Australia, was introduced into New Zealand in the early 1960s as a stowaway in a shipment of wooden railway sleepers (Chapple et al. 2012).

Norway rats (*Rattus norvegicus*) are thought to have originated from Asia but they have a long history of introductions, being introduced to many regions worldwide. These introductions are often associated with shipping with rats being able to stowaway on the ships or boats directly, however rats have also been observed escaping from cargo being unloaded (Russel et al. 2008).

4.3 Hitchhikers in or on airplane

Species that have been introduced unintentionally by being a hitchhiker in or on airplanes and other aircraft (e.g. helicopters, gliders)

Description

Hitchhiking species (species that are carried by chance or unknowingly) have been known to use vectors such as airplanes or other aircraft, such as helicopters, to move between locations including regions outside their natural range. This pathway does not apply to species that are contaminants of other species transported (intentionally or unintentionally) through airplanes which instead belong to pathways within the **Transport – Contaminant** category. The

pathway only applies to species that are interact with the airplane or aircraft itself (e.g. this is the point at which the species embarked and/or disembarked) and not to species that interact with any cargo, containers, packaging, people or luggage transported by the aircraft.

Similar or Related pathways

This subcategory can be confused with other pathways that contribute to the movement of taxa associated with air transport, e.g. **Container/bulk** and **People and their luggage/equipment**, **Machinery/equipment** pathways**.** The key distinguishing feature is that in the **Hitchhikers in or on airplane** the stowaway interacts with the airplane itself (e.g. this is the point at which the species embarked and/or disembarked) rather than the bulk air freight, cargo, people or belongings that may also be transported in the aircraft.

Examples

Various species of mosquito are known to board aircraft and hitchhike considerable distances. During a 9 month period in 1941-1942 the mosquito *Anopheles gambiae* (a major vector of malaria) was found on board aircraft flying from Africa to Brazil on seven different occasions. During these inspections 132 mosquitoes and two live tsetse flies were found. This study led the Brazilian government to insist that all aircraft arriving from Africa be disinfected with pyrethrum spray before disembarking. Similarly inspections carried out on 102 aircraft arriving at Miami during 1931 from the West Indies and Central America yielded 21 live *Culex quinquefasciatus* and one live *Aedes aegypti* (Gratz et al. 2000).

It is likely that the tree frog (*Scinax quinquefasciata*) was introduced to the Galapagos as a hitchhiker in/on cargo transported by airplane (Snell 1999)

4.4 Hitchhikers on ship/boat (excluding ballast water and hull fouling)

Species that have been introduced unintentionally by being a hitchhiker in or on ships, boats or other watercraft (e.g. hovercraft, submarines) but excluding species transported in ballast water or via hull fouling

Description

Hitchhiking species (species that are carried by chance or unknowingly) have been known to use vectors such as ships and boats to move between locations and to environments outside their natural range. This subcategory does not include species that are contaminants of other species transported (intentionally or unintentionally) by ships or boats which instead belong to pathways within the **Transport – Contaminant** category.

The pathway only applies to species that interact with the ship or boat itself (e.g. this is the point at which the species embarked or disembarked) and not to species that are associated with any cargo, containers, packaging, people or luggage transported by the ship or boat. This pathway excludes species which are transported via ballast water or hull fouling which have their own respective pathways (**Ship/boat ballast water** and **Ship/boat hull fouling)**. However, species transported with boat/ship in locations other than ballast water and hull fouling (namely where water is held or collected within the hull, such as sea chests, bilge water and within the hull itself, etc.) should be considered under this subcategory.

Similar or Related pathways

Some confusion may occur in the case of hitchhikers (or stowaways) carried in the ballast water of ship/boat or as a hull-fouling organism on ship/boat as these species are technically hitchhikers on the ship/boats. However, in both these cases there are specific categories that deal with these situations, namely **Ship/boat ballast water** and **Ship/boat hull fouling**, that should be used in preference to this more general pathway.

This pathway may also be confused with other pathways that can apply to the movement of taxa as stowaways on ship/boats, e.g. **Container/bulk** and **People and their luggage/equipment (in particular tourism)**. The key distinguishing feature is that in the **Hitchhikers on ship/boat** pathway the stowaway interacts with the ship/boat itself (e.g. this is the point at which the species embarked or disembarks) rather than the bulk/cargo, machinery, equipment, people or belongings that may also be transported by the ship or boat.

Examples

Species such as myna birds (*Acridotheres* Vieillot, 1816 spp.) and the house crow (*Corvus splendens*), are known to have moved respectively across locations in the Pacific and Australia (Parkes 2007), and to Europe (Fraser et al. 2015) via ship-assisted transfer. It is also likely that the tree frog (*Scinax quinquefasciata*) was introduced to the Galapagos as a hitchhiker in a ship/boat (Snell, 1999).

Rattus norvegicus, brown rat, probably arrived in Europe in the middle ages and then hitch-hiked around the world on boats, leading to accidental introductions to the Americas, Australia and Africa, as well as to island groups.

The killer shrimp (*Dikerogammarus villosus)* a Ponte-Caspian species, has been introduced to the UK in bilge water, released during bilge pumping.

4.5 Machinery/equipment

Species that have been introduced unintentionally by being a hitchhiker in or on machinery or equipment being transported between locations

Description

The movement and importation of heavy machinery and equipment, including imported goods such as vehicles, military equipment and any other material transported between location, e.g. in case of relief and rescue missions, are a potential risk pathway for stowaway species that can hide in small spaces and prove difficult to detect. Opportunities for stowing away include areas where the machinery/ equipment were used prior to shipment and in shipment storage areas. This subcategory does not include contaminants of organisms transported (intentionally or unintentionally) through **Machinery/equipment**, as they clearly fall within the category **Transport-Contaminant**.

Similar or Related pathways

This pathway can be confused with other sub-categories of **Transport-stowaway** that include the movement of machinery/equipment across locations using different modes of transport over land, sea and air, namely **Container/bulk** and **People and their**

luggage/equipment pathways. The distinguishing features to note are that in the **Machinery/equipment** pathway refers to the movement of stowaways associated with the **Machinery/equipment** itself (e.g. this is the point at which the species embarks) rather than the containers or bulk freight units that the machinery or equipment may be contained within. The **Machinery/equipment** pathway also is typically focused upon commercial or industrial machinery or equipment while the **People and their luggage/equipment** pathway is restricted to the personal equipment transported by travellers (e.g. in or as part of their luggage).

Examples

Asian house gecko (*Hemidactylus frenatus* Schlegel, 1836), in used and new vehicles; spiny palmed shining skink (*Cryptoblepharus carnabyi* Horner, 1991) in machinery (Biosecurity New Zealand, Ministry of Agriculture and Forestry, 2007).

Seeds of the alien invasive Common ragweed (*Ambrosia artemisiifolia* L.) have been transported in litter and soil by agricultural machinery from infested areas across Europe (Bullock et al. 2012).

4.6 People and their luggage/equipment (in particular tourism)

Species that have been introduced unintentionally by being a stowaway in or on people and their personal luggage or equipment

Description

The movement of people and their luggage/equipment between locations (at either the local, national, regional or international scale) for purposes of leisure, recreation, research, tourism etc. is a potential risk pathway for species that can stowaway and be transported to new locations outside their native range. The category is particularly targeted at tourists but covers any people travelling between regions.

Similar or Related pathways

Some confusion may exist with most of the other pathways under the **Transport-Stowaway** category, such as the **Angling/fishing equipment, Container/bulk, Hitchhikers in or on airplane, Hitchhikers on ship/boat, Machinery/equipment, Organic packing material, Ship/boat ballast water, Ship/boat hull fouling,** or **Vehicles** pathways. The key feature that distinguishes this pathway from the other **Transport-stowaway** pathways is that it refers only to species transported as stowaways on people themselves and/or their personal luggage or equipment, with the notable exception of the **Angling/fishing equipment**.

Some confusion may also arise in relation to the pathway within the **Transport-contaminant** category when contaminated items, e.g. foods, fauna, flora including seeds, are transported by travellers (on their person and/or in their luggage). In these cases, however the **Transport – contaminant** pathway appropriate for the contaminated items should be assigned, e.g. **Contaminated food** in the case of contaminated food, reserving the **People and their luggage/equipment** category for stowaway species associated with the person and/or their luggage.

Examples

Poa annua, annual meadow grass, from South Shetlands Islands has been shown to have arrived through a variety of pathways but personal outdoor equipment and bags, outdoor clothing and items (particularly pockets, seams, cuffs, boots and the hooks of fasteners) held many seeds of *P. annua*.

The harlequin ladybird (*Harmonia axyridis)* has been reported arriving in new regions in suitcases.

4.7 Organic packing material (wood packaging)

Species that have been introduced unintentionally by being a stowaway in or on packing materials such as boxes, pallets, saw dust, hay, straw, etc.

Description

Packaging material such as pallets, boxes, bags, baskets, wraps, tubes, crates, spools, dunnage etc. sourced from organic material such as unprocessed wood, cane, plant products etc. are used to transport commodities and cargo. This packaging material represent a potential pathway for the introduction of alien species to new environments.

Similar or Related pathways

This subcategory can be confused with the sub-category **Timber trade** of the **Transport-contaminant** category. The distinguishing feature between these two pathways is that the **Timber trade** is to be considered in the case of movement of contaminant organisms occurring on timber (note that contaminants are those taxa which are associated with a particular habitat and cannot survive without it), whereas, **Organic packing material (wood packaging)** is to be considered in the case of taxa being moved across locations as stowaways on packaging material. These taxa do not rely on the organic packaging material as a vital habitat for their survival as the contaminants moved via the **Timber trade** (e.g. usually invertebrates such as beetles, borers, ants etc.) do.

Some confusion may also exist with the **Container/bulk** subcategory, which however should be used only in case the alien organism is moved outside a specific packing material. For example, should the target species being moved inside some packing material stored into a container transported through a ship, the correct pathway to be considered is **Organic packing material (wood packaging)**.

Examples

A number of species of wood-boring beetle are known to be introduced to new regions through wood packing material used in international trade. *Anoplophora glabripennis*, native to China and the Korean peninsula, is one such species. It has been introduced throughout North America and Europe.

4.8 Ship/boat ballast water

Species that have been introduced unintentionally via the ballast water of ships and boats

Description

Ballast water that is pumped into tanks to stabilize cargo ships is continually loaded and discharged to balance a continually changing freight manifest. Water can be taken on in large quantities in one harbour and then discharged in the next; this may be a few kilometers away, or in new country several thousand kilometers away. When the water is taken on board or when it is discharged there are species and their propagules (including pathogens and algae), that may be spread around the world.

Similar or Related pathways

There could be some confusion with the **Ship/boat hull fouling**, or **Hitchhiker on ship/boat** pathways as they all refer to the introduction of species as stowaways on ships. The **Hitchhiker on ship/boat** is a general pathway that can apply to species transported as stowaways anywhere on a ship and therefore potentially overlaps with the more specific **Ship/boat hull fouling** and **Ship/boat ballast water** pathways. In general, the most specific pathway that is appropriate should be applied and therefore the hull fouling and ballast water pathways should be used in preference to the **Hitchhiker on ship/boat** pathway where species stowaway on the hull or in the ballast water. The **Ship/boat hull fouling** and **Ship/boat ballast water** pathways may also be confused as the ballast tank or sea chest are both structures build into the hull and species in these areas can potentially be sessile fouling species as well as free-living species. The distinction is that typically the **Ship/boat hull fouling** pathway focus on the exterior surface of the ship while the **Ship/boat ballast water** pathway focuses tanks and structures internal to the ship/boat (even though they will have openings to the hull). Species transported with ship/boats in locations other than ballast water and hull fouling (e.g. where water is held or collected within the hull, such as sea chests, bilge water and within the hull itself) should not be considered under this subcategory, as they are included under **Hitchhikers on ship/boat (excluding ballast water and hull fouling)**.

Examples

Three Eurasian species, Spiny Waterflea (*Bythotrephes longimanus* Leydig, 1860), Eurasian Ruffe (*Gymnocephalus cernuus*) and Zebra Mussel (*Dreissena polymorpha*) were reported from the Laurentian Great Lakes, North America (Bailey, 2015). likely as result of ballast water discharge (Hebert et al., 1989).

4.9 Ship/boat hull fouling

Species that have been introduced unintentionally as hull-fouling organisms on ships and boats

Description

Ships also move simple sessile species when these attach themselves to the ship and form colonies or communities on a ship's hull. Such colonies or communities can develop during a voyage, or between periods of anti-fouling treatment, and are spread merely by their normal processes of reproduction being on a mobile substrate. In addition to reproducing and

spreading by simply being on the hull of boasts and ships, hull-fouling organisms can be spread unintentionally, when a ship has its hull cleaned. Species that are removed, if not carefully disposed of, can establish locally. This category does not include species transported with ship/boats in locations other than hull fouling, for example those transported in held or collected within the hull, such as sea chests, bilge water and within the hull itself, etc. are included under **Hitchhikers on ship/boat (excluding ballast water and hull fouling)**.

Similar or Related pathways

There could be some confusion with the **Ship/boat ballast water**, or **Hitchhiker on ship/boat** pathways as they all refer to the introduction of species as stowaways on ships. The **Hitchhiker on ship/boat** is a general pathway that can apply to species transported as stowaways anywhere on a ship and therefore potentially overlaps with the more specific **Ship/boat hull fouling** and **Ship/boat ballast water** pathways. In general, the most specific pathway that is appropriate should be applied and therefore the hull fouling and ballast water pathways should be used in preference to the **Hitchhiker on ship/boat** pathway where species stowaway on the hull or in the ballast water. The **Ship/boat hull fouling** and **Ship/boat ballast water** pathways may also be confused as the ballast tank or sea chest are both structures build into the hull and species in these areas can potentially be sessile fouling species as well as free-living species. The distinction is that typically the **Ship/boat hull fouling** pathway focus on the exterior surface of the ship while the **Ship/boat ballast water** pathway focuses tanks and structures internal to the ship/boat (even though they will have openings to the hull).

Examples

Following the eradication of the black striped mussel (*Mytilopsis* sp.) from marinas within Darwin harbour (Australia), it was subsequently (within two years) detected on yachts, commercial fishing vessels and apprehended illegal vessels seeking entry to Darwin harbour alongside another alien species the Asian green mussel (*Perna viridis).*

Recreational boats have been a major vector for the spread of the zebra mussel (*Dreissena polymorpha)* and invasive alien macrophtyes between lakes and rivers within Europe, the USA and New Zealand.

Rapana venosa has been introduced to new areas through a variety of pathways, including shipping (ballasts and fouling).

4.10 Vehicles (car, train, …)

Species that have been introduced unintentionally by being a hitchhiker in or on vehicles such as cars, vans, lorries, trucks, trains, etc. that are not covered by the other stowaway pathways

Description

Common modes of transport including cars, vans, lorries, trucks, trains etc. have the potential to be vectors of stowaway species that can hide in any available spaces, introducing them to

areas outside their native range. This pathway includes any species that transported as stowaways within any vehicles that are not covered by the other stowaway pathways.

This subcategory does not include contaminants of organisms transported (intentionally or unintentionally) in vehicles such as car, train, etc. as they fall within the category **Transport-Contaminant** pathway category. The pathway also only applies to species that are associated with the vehicles themselves (e.g. this is the point at which the species embarked) and not to species that associated with any cargo, containers, packaging, people or luggage transported by the vehicles.

Similar or Related pathways

This subcategory can be confused with other pathways that contribute to the movement of taxa associated with road/rail transport, such as the **Container/bulk** and **People and their luggage/equipment** pathways. The key feature is that pathway only applies to species that are associated with the vehicles themselves (e.g. this is the point at which the species embarked or disembarked) and not to species that are associated with any cargo, containers, packaging, people or luggage transported by the vehicles.

Examples

Common ragweed (*Ambrosia artemisiifolia*) was introduced as a stowaway on vehicles and machinery, passing through contaminated regions and towns. Seeds transported in litter and soil by agricultural machinery from infested areas is widely reported. Spread by mowing machinery is less studied, but is probably also important. (Bullock et al. 2012).

4.11 Other means of transport

Species that have been introduced unintentionally by being a hitchhiker in or on other means of transport other than those already covered by the other stowaway pathways

Description

This subcategory includes any other pathway responsible for the transport of organisms as stowaway not already explicitly indicated in the pathways within the **Transport-stowaway** category. This pathway therefore must be considered suitable for any organisms moved with a means of transport other than airplanes (and helicopter), boats/ship, vehicles, machinery, travelers/tourists etc. Examples are the fouling from offshore oil and gas platforms (IPIECA/OGP, 2010), offshore renewable energy sites (such as wind farms, see Adams et al. 2014), pipelines, cable transport, etc.

Similar or Related pathways

It is unlikely to confuse this subcategory with others, as any situation that does not fall under the definition of the other subcategories related to the **Transport-stowaway** category, would qualify for the present one.

Examples

In the Canary Islands the introduction of at least eight species of tropical littoral fish has been associated to transport connected with oil platforms' fouling, a pathway considered directly

linked to the arrival of oil platforms to the two main ports for the purposes of cleaning and repair works (Falcón et al. 2015).

5 Corridors

Species spreading to new regions along artificially created infrastructure corridors such as bridges, tunnels, canals.

Description

The **Corridors** pathway category refers to movement of alien species into a new region following the construction of transport infrastructures in whose absence spread would not have been possible. Such corridors include infrastructures built in marine or other aquatic environments, such as canals (connecting river catchments, lakes and seas) and tunnels or bridges, but also roads and railways, linking terrestrial environments, such as mountain valleys or oceanic islands.

Similar or Related pathways

A certain degree of confusion with the subcategories of the **Transport – Contaminant** and **Transport – Stowaway** related pathways may be expected, the only difference being that the introduction through the **Corridors** related pathways occurs without the contribution of any specific vector. In fact the species will move through the infrastructures serving as **Corridors** with its own capabilities. It is also distinguishable from the **Unaided** category as it the latter case the species is expected to move without any support from humans, infrastructures included.

Green infrastructures built to increase interconnectivity between environments may also be considered as **Corridors**, namely when they favour species which take advantage of their presence for spreading, hence not when the alien species that is favoured is the same used to build them, as they would fall under the **Landscape / flora / fauna "improvement" in the wild** pathway.

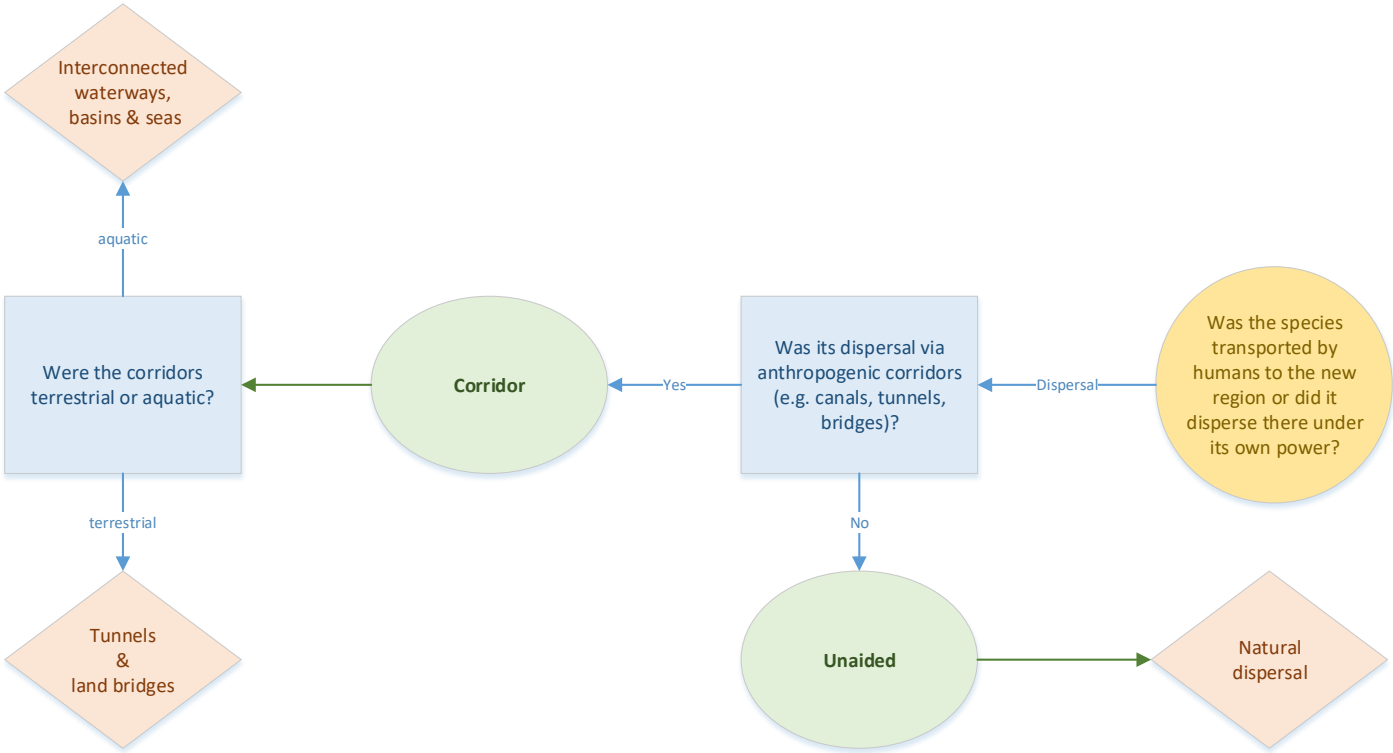


Figure 9 A schematic outlining the decision process for allocating pathways within the **Corridor** or **Unaided** categories. To use this schematic, begin at yellow circle, or jump directly to the green oval for the relevant category, proceeding through diagram by answering the questions in the blue boxes and following the arrows with the appropriate answers until ending at a subcategory (red diamond). It is important to note that for species can be arrived in a given region by multiple methods and in these cases it will be necessary to go through this decision process multiple times in order to assign all the appropriate pathways. This schematic is a section of a larger flowchart outlining the entire decision process down to the subcategory level across all categories.

5.1 Interconnected waterways / basins / seas

Species that spread to new regions by dispersing through artificial waterways connecting previously unconnected water bodies, basins or seas

Description

The **Interconnected waterways / basins / seas** pathway refers to the spread of species to new regions facilitated by the construction of new canals or other artificial waterways interconnecting previously unconnected water bodies, basins and seas. Increase in trade and the desire to reduce the time and cost of moving commodities between locations has resulted in the construction of artificial waterways providing direct routes between formerly isolated water bodies. A few examples of the type of artificial waterways referred to by this pathway are the Trans-European Inland Waterway network, which is a network of waterways connecting navigable rivers and man-made canals across Europe (connecting over 35 countries), the Suez Canal (connecting the Mediterranean Sea to the Red Sea), or Panama Canal (connecting the Atlantic Ocean to the Pacific Sea).

Similar or Related pathways

The **Interconnected waterways / basins / seas** pathway can be confused with the **Natural dispersal** pathway within the **Unaided** pathway category. The key distinguishing feature is that the former pathway refers to the natural dispersal of species between regions through artificial waterways or waterbodies that connect previously unconnected water systems or bypass inhospitable regions, while the latter pathway refers to the natural unassisted dispersal of alien species to new environments.

The **Interconnected waterways / basins / seas** pathway may also be confused with the **Tunnels and land bridges** pathway in situations where species have spread in waterbodies that pass through man-made tunnels and/or over man-made bridges (e.g. aquaducts). In this case however this species are still dispersing via the water systems which have been routed or connected artificially and therefore the **Interconnected waterways / basins / seas** pathways is the relevant pathway and should be assigned.

Confusion may also occur between the **Interconnected waterways / basins / seas** pathway and any of the shipping related pathways in the **Transport – Stowaway** category, such as the **Hitchhikers on ship/boat**, **Ship/boat ballast water**, **Ship/boat hull fouling** and possibly **Container / bulk** pathways. The confusion can arise when species are transported by shipping and the ship itself travels by or through artificial waterways, e.g. ships passing through the Red Sea. In this situations the species should only be assigned to the relevant shipping pathway (e.g. **Hitchhikers on ship/boat**, **Ship/boat ballast water**, etc.) and not to the **Interconnected waterways / basins / seas pathway** although it can be useful to record that the shipping is via artificial waterways in notes or description accompanying the pathway category assignment**.**

Example

Lessepsian migrations, the phenomenon regarding the movement of marine species across the Suez Canal, usually from the Red Sea to the Mediterranean, is a typical example of a corridor pathway created by humans to interconnect seas and favouring the introduction of species outside their native range. For example, all the recorded alien fishes of Cyprus are Lessepsian migrants, 80% of which can be considered established and four of them are invasive (Iglésias and Frotté 2015).

The pufferfish (*Lagocephalus sceleratus*) spread from the Red Sea through the Suez Canal to the Eastern Mediterranean being first recorded in Turkey in 2003. Since then the species has spread westwards in the Mediterranean via natural dispersal towards Italy (recorded at the Italian island of Lampedusa in 2013) and Tunisia.

The Schyphozoan jellyfish (*Rhopilema nomadica*) also spread from the Red Sea through the Suez Canal to the Mediterranean being first recorded of the Israeli coast in the mid-1970s. Since then the species has become increasingly common in the Eastern Mediterranean.

5.2 Tunnels and land bridges

Species that spread to new regions by dispersal using artificial tunnel or bridges, or other infrastructures, such as roads and railways.

Description

The **Tunnels and land bridges** pathway refers to the spread of taxa beyond their natural range using artificial tunnels and land bridges to bypass inhospitable regions and/or to reach locations that they previously could not. Artificial tunnels and bridges facilitate the movement of people and goods by providing direct connections between locations and/or by bypassing areas that are difficult or impossible to navigate by other means (e.g. rivers, mountains, seas, etc). Tunnels and bridges can provide a similar function for flora or fauna enabling them to spread to new regions, therefore they have the potential to be a pathway for the spread of alien species.

Similar or Related pathways

The **Tunnels and land bridges** pathway can be confused with the **Natural dispersal** pathway within the **Unaided** category as both pathways refers to alien species spreading by natural dispersal. The distinction between them is that in the **Tunnel and land bridges** pathway this spread has utilised artificial structures, namely tunnels or bridges, to cross inhospitable terrain such as mountain ranges, rivers or seas.

The **Tunnels and land bridges** pathway may also be confused with the **Interconnected waterways / basins / seas** pathway in situations where species have spread in waterbodies that pass through artificial tunnels and/or over artificial bridges (e.g. aqueducts). In this case however this species are still dispersing via the water systems which have been routed or connected artificially and therefore the **Interconnected waterways / basins / seas** pathways is the relevant pathway and should be assigned.

Examples

Siberian Chipmunk (*Tamias sibiricus*) in the UK has been suggested to have arrived by the Channel Tunnel by the British media.

In New South Wales for example, a factor in dispersal of Common Mynas (*Acridotheres tristis*) has been the use of roads and maybe railways as corridors to towns previously uncolonized, though this could be biased because these are the sites of most intense observation (Hone 1978). Similarly, in South Africa the species seems common along major roads (Peacock et al. 2007).

6 Unaided

Species that spread to new regions by natural dispersal, without action or assistance by humans, from regions in which they are alien and were introduced by one of the other introduction pathways

Description

This pathway category only contains a single pathway and therefore the description, similarly or related pathways and examples are the same as those given for the **Natural dispersal** pathway below.

In general, this category refers to secondary dispersal, as the species must already be alien in the region from where the unaided dispersal occurs.

6.1 Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5

Species that spread to new regions by natural dispersal, without action or assistance by humans, from regions in which they are alien and were introduced by one of the other introduction pathways

Description

Species are only regarded as alien if they are introduced to a region outside of their natural range through human activity, such as the pathways described previously in the other pathway categories (**Release in nature**, **Escape from confinement**, **Transport – Contaminant**, **Transport – Stowaway**, and **Corridor**). However, once an alien has been introduced to a region it can disperse naturally, without human action or assistance, from that region spreading into surrounding regions. It is this spread of alien species via natural dispersal from regions in which they were introduced to other surrounding regions (in which they are also not native) that is covered by this pathway. The borders in question will typically be national border, but can be sub-national (particularly in the case of large counties like Russia, USA, Australia, etc.).

This category includes alien species introduced as a contaminant of migratory species (e.g. birds, fish or ungulates), which move without human assistance, yet can act as a vector of alien species transported through the mud in their feet, or stuck in fur/feathers.

Similar or Related pathways

The **Natural dispersal** pathway can be confused with the **Tunnel and land bridge** or **Interconnected waterways / basins / seas** pathway in the **Corridor** pathway category as each refers to alien species spreading by natural dispersal. The distinction between them is that in the **Tunnel and land bridges** and **Interconnected waterways / basins / seas** pathways this spread has utilised human constructed structures, namely tunnels, bridges or artificial waterways, to cross inhospitable terrain such as mountain ranges, rivers or seas or to connect previously unconnected water systems. In contrast the **Natural dispersal** pathway only applies in situations where the dispersal is completely natural and without action or assistance of humans other than the original introduction to the source region.

In this regard, some confusion may exist with the **Contaminant on animals** pathway, for example in case of alien species introduced as a contaminant of migratory species (e.g. birds, fish or ungulates). However, since they move without human assistance (which is a prerequisite for being considered under the **Transport-contaminant** category) the correct category is **Natural dispersal.**

Examples

The Ruddy duck (*Oxyura jamaicensis*) is a native to the Americas that was intentionally introduced to the United Kingdom in the 1930s and 1940s for display in wildfowl collections, both publicly displayed ones as well as private collections (**Pet / aquarium / terrarium species** and **Botanical garden / zoo / aquaria** pathways). Individuals from these collections escaped into the wild and became established with the first record of breeding in the wild being in 1952. From the UK the species spread naturally, hence through the **Natural dispersal** pathway, into other European countries (e.g. France, Netherlands, Belgium, and Spain).

Suggestions & recommended best practices for recording introduction pathway information

The importance of recording more than just the pathway category

Concise descriptions of pathway specifics

It is important to note that there is considerable benefit in including concise descriptions of each pathway that cover the key specifics of the pathway. These descriptions allow users to understand the context of the pathway assignment without requiring reference to additional sources of information. Additionally, documenting both the pathway category and providing a detailed description of the pathway for each taxa allows users to ensure that the pathway category corresponds with the description and also facilitates any reclassification or realignment of the pathway classification in the future. For example, when exchanging data between systems using different approaches to classification or aligning data from different systems for analysis.

Furthermore, it can be useful to store and/or categorise key attributes relating to the pathway to increase the utility of the data, for example providing specific details of the exact nature of the introduction where known. This could also facilitate increased resolution of pathway information for end users such that it may be possible to identify emerging trends in pathways. For example, it may become apparent that a particular plant within the "Contaminant of plants" subcategory is associated with an IAS of concern.

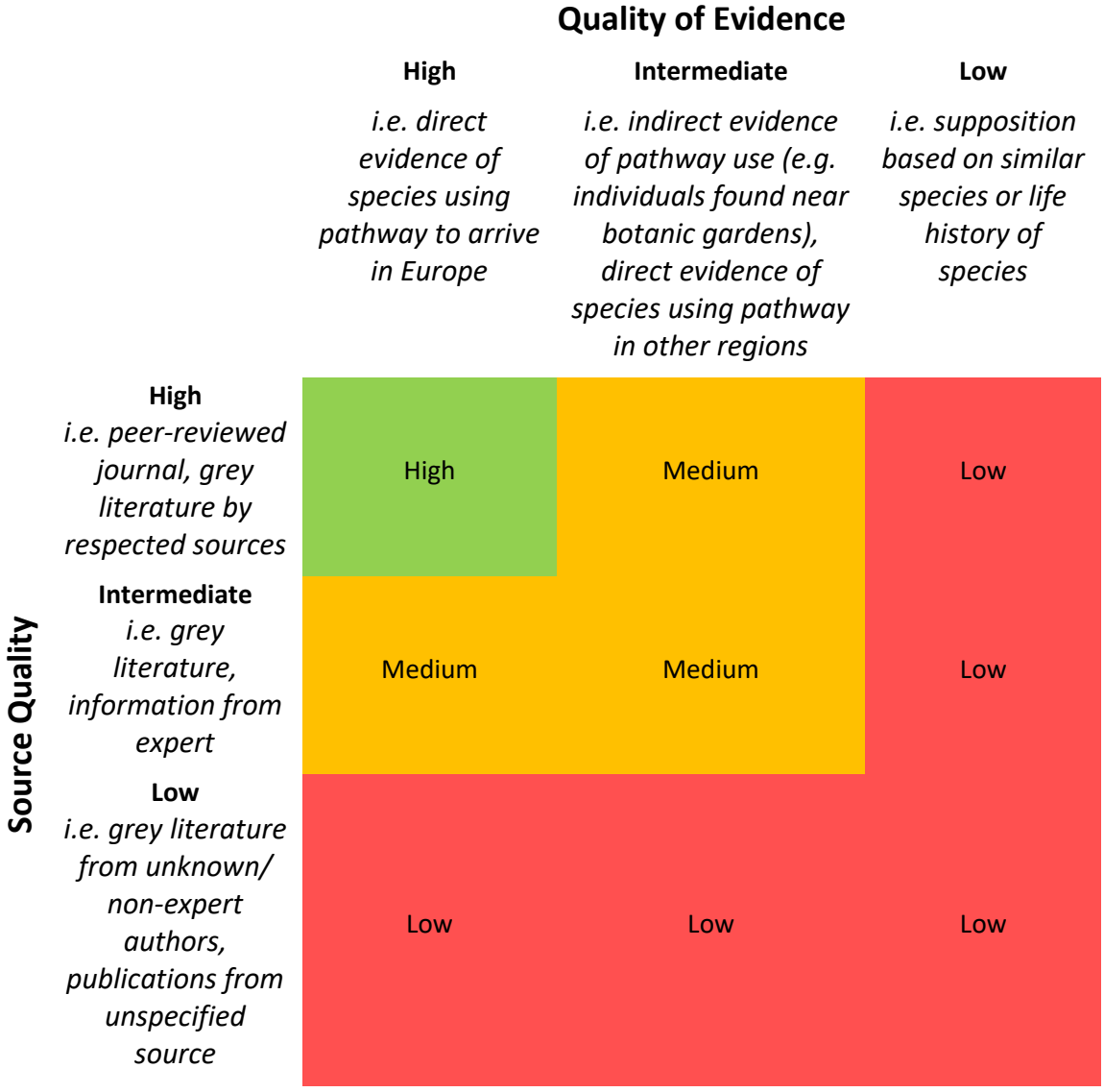
Level of confidence or evidence

When attributing a pathway to an introduction event for a species it can be useful to provide the level of confidence and / or document the evidence upon which the classification is based. This can be as simple as using a few categories to separate pathways that are based on inference or expert opinion as opposed to those for which there is direct evidence.

There are various approaches to scoring confidence (e.g. Moss and Schneider 2000, IPBES 2016), one such approach is the one that was used within the mentioned EC funded project (ENV.B.2/SER/2015/0037rl) which updated the EASIN categories. In this project certainty in each pathway assignment was considered to be determined by a combination of two main factors. These two factors were the quality of source itself in which the information was presented and the quality of the evidence itself underpinning the pathway information. The overall confidence in the pathway assignment was allocated to one of three categories; low, medium, high; based on the trade-off between these two factors (**Table 3**). For example, a pathway assignment based upon information in a peer-reviewed paper which gives direct evidence of transport of a species by the pathway assigned in the target region would have high certainty, while an assignment based on a statement in a national database or a piece of grey-literature that is not backed up by any evidence or credited to a reliable source would be classed as low certainty. As mentioned above this approach is only one of many approaches that can be used to assign a level of confidence to pathway information. Other approaches can take into account other factors such as any uncertainty in trying to assign pathway

information to a categorisation system, e.g. some information is easy to categorise whilst for others it is less clear cut.

Table 3 An example of the kind of guidelines that can be used to determine the certainty or confidence of the pathway information. This is the approach that was used in an EC funded project to align introduction pathway information held for species in the EASIN database to the CBD categorisation scheme. This is only one of many possible way to determine the degree of certainty and it only considers two of many possible factors that could influence the confidence in any pathway information.



Multiple pathways

Although in some cases alien species are introduced by a single introduction pathway in many others they can arrive via a number of pathways (Pergl et al. 2016). In these instances each appropriate pathway should be assigned to the species so that the data contains as a comprehensive list of the introduction pathways for that species as possible. Where species

can arrive by multiple pathways, however, it is unlikely that each pathway is equal in their potential for introduction, but rather introduction pathways will differ in key properties that can influence the introduction potential, such as number/frequency of introduction events, size of introduction events, genetic diversity, etc. (Wilson et al. 2009). It can therefore be useful to score or categorise pathways based on their contribution. Doing this, even if only at a basic level (such as scoring pathways as either major or minor pathways), gives more nuance to the data and enables more sophisticated analysis or comparisons. Additionally it is worth considering that alien species may further spread and disperse between points within or between neighbouring regions through secondary pathways, which often differ from the primary ones.

Time period

The pathways through which species are introduced, and their relative importance, are not static but will vary over time. For instance, previously dominant pathways can wane in importance, or even disappear, while new or minor pathways can increase in importance (Essl et al. 2015). These changes in the introduction pathways are driven by changes in the world economy, cultural attitudes, regulations and legislation and other factors. For example, the importance of a pathway will vary as the flow of goods from/to that region increases and/or decreases, or as laws and regulations are implemented to control prominent pathways and/or reduce the risk of introduction of alien taxa. Similarly the importance of pathways may diminish or increase as attitudes and behaviours change, such as the reduction in importance of the **Landscape / flora / fauna "improvement" in the wild** pathway, increase in importance of the **Pet / aquarium / terrarium species** pathway. Given the dynamic nature of the temporal variation in introduction pathways it can be useful to assign information on dates or time periods to each pathway. Such information can be used to indicate whether pathways are historic (e.g. pathways that were previously important but are now no longer as important), current (e.g. pathways that are currently important for the introduction of the species), or suspected to be important in the future (e.g. pathways that are not currently important but are on the rise or that are likely to be important in the future). This information would have fundamental implications to assess temporal trends and allow fine tuning of risk assessment and/or management strategies to reflect this dynamic process.

Region

In addition to temporal variation in the pathways, and their relative importance, introduction pathways can vary between regions. Given this spatial variation, it is important to explicitly record the receiving region, and if known also the donor region. This spatial variation will be influenced by differences between the regions in key economic factors such in trade routes, the goods and commodities being traded and also the regulations or laws governing imports in the region as well as those with which it trades. It is, therefore, not always appropriate to extrapolate from one region to another, as factors influencing a pathway in one region may not apply in another. This is not to say, however, that knowing information about introduction pathways from other regions is not beneficial. The fact that a species has been shown to be introduced to one region by a specific pathway does indicate a potential for that species to arrive at new regions via that pathway.

Finer resolution pathways

It is also important to remark that a more detailed level of description of pathways may be required, i.e. depending on the specific focus of the different datasets or institutions. In particular, more detailed subcategories could be developed, e.g. at the country or local level, or for specific pathways (see also Scalera et al. 2016). For example, within the pet trade it may be useful to more detailed subcategories to allow distinction between terrestrial pets, aquarium species, exotic pets, live food, etc.. However, this would require a new detailed analysis of pathways across databases and literature, including extensive consultation with relevant experts. In addition given the context-specific nature at finer resolutions is it less likely that these will be useful global generalisations. The goal of finer resolutions should be to be of value to particular management contexts.

Dependent pathways

Typically, the pathway category assigned to a species is the pathway(s) that relates directly to the species being introduced. However, there are situations in which the introduction of a species is also indirectly dependent on another pathway, particularly where the species is contaminant of another species or product. For example, in the case of an invertebrate pest on an ornamental plant the direct pathway (i.e. that relating directly to the species being introduced) would be **Contaminant on plants** while the indirect pathway would be the pathway through which the ornamental plant was transported, e.g. **Ornamental other than horticulture**. Although these dependent pathways are not directly related to the species they play a part in understanding the process of introduction and are, therefore, important for decision-making and particularly in relation to prevention through management of pathways. As these dependent pathways are important they should be recorded, but as they are not directly related to the species it is important they are not confused with the pathway information that directly relates to the species. Therefore, they need to be highlighted or marked in an appropriate way to indicate that they operate on the species indirectly through dependency upon another species or product. Exactly how this information is shown or recorded will depend on where the information is being present or stored, from a simple text description in a document or report to a more complex database system flagging dependent pathways and allowing them to be linked to the corresponding direct pathway.

Suggested alterations to CBD Pathways Categorisation

The CBD pathways categorisation as published in the CBD note UNEP/CBD/SBSTTA/18/9/Add.1 (CBD 2014a) is a useful framework. However, there are a few ways in which it could be modified slightly to improve clarity and logical application. The first suggested alteration is to alter the pathway titles so that they are short descriptive titles providing a concise way of referring to each pathway suitable to be used in documents, figures or diagrams. Suggested replacements for the CBD pathway category and subcategory titles are provided in the tables below (**Table 4** and **Table 5** respectively). By attempting to shorten the titles it can be argued that we are losing specificity but it is suggested the classification scheme uses the new title provided but also used the descriptive sentence provided for each subcategory in this document (in italics beneath the existing titles in the descriptions section).

In the majority of cases these titles aim simply to shorten the pathway titles, but in a few cases the changes potentially alter the interpretation of the pathway. The most notable change

is for the **Organic packing material, in particular wood packaging** pathway which it is suggested to be retitled to **Packing materials**. The existing titles enforces a restriction in the pathway, specifically that the packing materials be organic, which implies that the species should have an ecological relationship with the packing materials. This implication of an ecological relationship is not consistent with this pathway being within the **Transport – stowaway** category as in this case the association between the species and the items or products it is being transported should be temporary.

It is also suggested that the **Contaminant on animals**, **Parasite on animals**, **Contaminant on plants**, and **Parasites on plants** pathways all be renamed to replace the "on" in the title with "of", e.g. **Contaminant of animals**. This change is suggested to make it clearer that these categories refer to species transport on or in the species. As it currently stands the title implies that these categories should only be used for species that are transported externally on the plant or animal.

In addition to alterations of the names it is suggested that the two miscellaneous pathways in the **Release in nature** category, **Release in nature for use** and **Other intentional release**, be merged to form a single pathway. This merged pathway would apply to all intentional introductions that do not fit the other more specific **Release in nature** pathways, and a suggested title for this pathway would be **Other release**. In addition to merging these pathways it is suggested that a new miscellaneous pathway be added to the **Transport - Contaminant** category. This is suggested as all the other pathway categories with the exception of this one include a miscellaneous category to be assigned in cases where none of the other specific pathways are applicable. The suggested title for this new pathway would be **Other contaminant**.

Table 4 Suggested title changes for the pathway categories presented in the CBD pathway categorisation scheme. There is no suggested change for the Corridor or Unaided categories as these titles are already concise

Category title	Suggested title
Release in nature	Release
Escape from confinement	Escape
Transport – Contaminant	Contaminant
Transport – Stowaway	Stowaway
Corridor	Corridor
Unaided	Unaided

Table 5 Suggested title changes for the pathway subcategories presented in the CBD pathway categorisation scheme. The entries in italics (marked with an asterisk*) are pathway subcategories that are suggested either for removal, in the case of the **Release in nature for use**, or are a new pathway suggested for addition to the scheme, in the case of the **Other contaminant**.

Category	Subcategory title	Suggested title
Release	Biological control	Biological control
	Erosion control / dune stabilization (wind breaks,	Stabilisation &

	hedges, …)	Barriers
	Fishery in the wild	Fishery in wild
	Hunting	Hunting
	Landscape / flora / fauna “improvement” in the wild	Aesthetic release
	Introduction for conservation purposes or wildlife management	Conservation in wild
	Release in nature for use (other than above, e.g. fur, transport, medical use)[*]	
	Other intentional release	Other release
Escape	Agriculture (including Biofuel feedstocks)	Agriculture
	Aquaculture / mariculture	Aquaculture
	Botanical garden / zoo / aquaria (excluding domestic aquaria)	Botanical gardens & Zoos
	Pet / aquarium / terrarium species (including live food for such species)	Pet
	Farmed animals (including animals left under limited control)	Farmed animals
	Forestry (including reforestation)	Forestry
	Fur farms	Fur farms
	Horticulture	Horticulture
	Ornamental purpose other than horticulture	Ornamental
	Research and ex-situ breeding (in facilities)	Research
	Live food and live bait	Live food & live bait
	Other escape from confinement	Other escape
Contaminant	Contaminant nursery material	Nursery material contaminant
	Contaminated bait	Bait contaminant
	Food contaminant (including of live food)	Food contaminant
	Contaminant on animals (except parasites, species transported by host/vector)	Contaminant of animals
	Parasites on animals (including species transported by host and vector)	Parasite of animals
	Contaminant on plants (except parasites, species transported by host/vector)	Contaminant of plants
	Parasites on plants (including species transported by host and vector)	Parasite of plants
	Seed contaminant	Seed contaminant

	Timber trade	Timber trade contaminant
	Transportation of habitat material (soil, vegetation)	Habitat material contaminant
		Other contaminant[*]
Stowaway	Angling / fishing equipment	Fishing equipment
	Container / bulk	Container & bulk cargo
	Hitchhikers in or on airplane	Airplane
	Hitchhikers on ship / boat (excluding ballast water and hull fouling)	Ship excluding ballast water or hull fouling
	Machinery / equipment	Machinery & equipment
	People and their luggage/equipment (in particular tourism)	People & luggage
	Organic packing material, in particular wood packaging	Packing material
	Ship / boat ballast water	Ballast water
	Ship / boat hull fouling	Hull fouling
	Vehicles (car, train …)	Land vehicles
	Other means of transport	Other stowaway
Corridor	Interconnected waterways / basins / seas	Canals and artificial waterways
	Tunnels and land bridges	Tunnels and bridges
Unaided	Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5	Natural dispersal

Glossary

Alien (= non-native) species, subspecies or lower taxon, introduced outside its natural past or present distribution by direct or in-direct human action; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.

Invasive alien species (IAS) - species whose introduction and/or spread outside their natural past or present distribution threatens biodiversity, society and economies.

Pathway - processes that result in the introduction of an alien species from one geographical location to another

Vector - mode of introduction for example, a ship, cargo containers, packing materials, equipment or transport vehicles,

Primary pathway - move species to new regions or provinces across biogeographic barriers (oceanic, landmass or climatic barriers (i.e. trans-oceanic and intercontinental pathways))

Secondary pathways - spread and disperse alien species between points within or between neighbouring regions (secondary pathways often differ from the primary ones).

Stowaway - a species that uses vectors to move between locations by chance or unknowingly

Contaminant – a species that has an ecological association with, and/or dependence on, a specific organism or product.

Parasite or pathogen - organisms that live in or on a host and obtain their food from the host at a cost to the host.

Acrynoyms

IAS – Invasive Alien Species

CBD - Convention on Biological Diversity

CEH - Centre for Ecology and Hydrology

COST – European Cooperation in Science and Technology

DAISIE – Delivering Alien Species Inventory for Europe

EPPO – European and Mediterranean Plant Protection Organisation

EC – European Commission

EU – European Union

GIASIP - Global Invasive Alien Species Information Partnership

IUCN SSC-ISSG - IUCN Species Survival Commission

MS – Member State

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