Understanding pathways of introduction and their identification

The Kunming-Montreal Global Biodiversity Framework has 23 action-oriented global targets for urgent action over the decade to 2030, and one of these, target 6, aims to address threats posed by invasive alien species (Box 1).

> ## Box 1. What are invasive alien species?
>
> An alien species is a species, subspecies or lower taxon, introduced outside its natural past or present distribution; this includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce[1]. An invasive alien species is an alien species whose introduction and/or spread threaten biological diversity.
>
> Invasive alien species are one of the major drivers of biodiversity loss, and cause dramatic, and in some cases irreversible changes to ecosystems[2]. They have contributed solely or alongside other drivers to 60 per cent of recorded global extinctions and are the only driver in 16 per cent of documented global extinctions[3]. Their impacts occur through different interactions, such as out-competing or predating upon native species, hybridisation, transmission of diseases, or biofouling.

The target aims to eliminate, minimize, reduce and/or mitigate the impacts of invasive alien species on biodiversity and ecosystems. To achieve this, the target sets out three overarching actions, one of which aims to identify and manage pathways of introduction of invasive alien species, the second to prevent the introductions and establishments of new invasive alien species, and the third to eradicate or control existing invasive alien species.

The identification of pathways, both past and present, and their prioritisation for management actions is therefore fundamental for meeting Target 6.

1   CBD COP Decision VI/23 Alien species that threaten ecosystems, habitats or species.
2   IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E.S. Brondízio, H.T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K.A. Brauman, S.H.M. Butchart, K.M.A. Chan, L.A. Garibaldi, K. Ichii, J. Liu, S.M. Subramanian, G.F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y.J. Shin, I.J. Visseren-Hamakers, K J. Willis, and C.N. Zayas eds.. IPBES secretariat, Bonn, Germany. https://zenodo.org/records/3553579
3   IPBES. (2023). Summary for policymakers of the thematic assessment report on invasive alien species and their control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Roy, H.E., Pauchard, A., Stoett, P., Renard Truong, T., Bacher, S., Galil, B.S., Hulme, P.E., Ikeda, T., Sankaran, K.V., McGeoch, M.A., Meyerson, L.A., Nuñez, M.A., Ordonez, A., Rahlao, S.J., Schwindt, E., Seebens, H., Sheppard, A.W., and Vandvik, V. (eds.). IPBES secretariat, Bonn, German. https://doi.org/10.5281/zenodo.7430692

What are pathways of invasive alien species introduction?

The first stage of the invasion process is human-assisted movement of living organisms (or propagules) beyond their native range, which is associated to several pathways and vectors.

In invasion ecology, **pathways** are defined as the routes and mechanisms of the introduction and spread of invasive alien species[4]. However, the term 'pathway', as currently used in the invasion literature, is more complex, as it represents a "combination of processes and opportunities resulting in the movement of propagules from one area to another, including aspects of the vectors involved, features of the original and recipient environments, and the nature and timing of what exactly is moved"[5] (Box 2).

Box 2. Definitions of pathways and vectors[6]

Pathways:
- 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.

Vectors:
- physical means or agent (i.e. aeroplane, ship) in or on which a species moves outside its native range (past or present).

Pathways and vectors can lead to both intentional and/or unintentional introductions. Examples of the latter are activities, such as fisheries, agriculture, forestry, horticulture, shipping (including the discharge of ballast waters), ground and air transportation, construction projects, landscaping, aquaculture including ornamental aquaculture, tourism, research, the pet industry and game-farming[7]

The increase in globalisation is considered the main driver of species movement around the world. Globalisation is associated with an increase in transport, trade, travel and tourism which provide pathways for species to cross those biogeographical barriers that limited their native range. 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 preventing the movement and spread of alien species, hence for managing the threat they pose to native species and habitats.

Identifying and prioritising the pathways of species introduction into a territory is the first step towards developing pathway action plans. A standardised pathway terminology and classification framework has been established by CBD.[8]

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4   Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species https://eur-lex.europa.eu/eli/reg/2014/1143/oj
5   Richardson, D.M., Pyšek, P. and Carlton, J.T. (2011). A compendium of essential concepts and terminology in invasion ecology. In: Fifty years of invasion ecology. The legacy of Charles Elton. Richardson, D.M. ed.. Wiley-Blackwell, Oxford. pp. 409 – 420.
6   Genovesi, P. and Shine, C. (2004). European strategy on invasive alien species: Convention on the Conservation of European Wildlife and Habitats (Bern Convention). Council of Europe https://www.cbd.int/doc/external/cop-09/bern-01-en.pdf
7   CBD COP Decision VI/23 Alien species that threaten ecosystems, habitats or species.
8   Pathways of introduction of invasive species, their prioritisation and management UNEP/CBD/SBSTTA/18/9/Add.1 www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf

Identifying pathways of introduction

Identifying and prioritising the pathways of introduction of past and future alien species introductions into the territory is the first step towards developing pathway action plans. Ideally this information will be collated during the generation of the species lists and will use the standardised pathway terminology and classification produced under the CBD (Annex I).

Identification of the actual (and potential) pathways involved in the introduction and spread of an alien species can be challenging. To support this process, some guidance[9] has been developed, including decision tree flow charts, and species examples for each pathway.

The pathway of introduction for many species may not be known for certain because of lack of documented evidence, and may need to be inferred retrospectively, e.g. by considering pathways assigned to the same species in other countries, or through expert consultation. Moreover, more than one pathway can be assigned to a species.

Consideration of pathways of introduction could be extended to include the pathways of spread, as many alien species may be introduced into a territory by one pathway (e.g. aquarium trade) but then spread via another (e.g. biofouling on boats).

Once the pathways have been allocated to all listed species of a given area and within a defined timeframe, it will be possible to assess patterns and trends in pathways of introduction. This will allow for the identification of those pathways that have led to the introduction of alien species in the past, and those that are relevant for future introductions, as they may be different. It is also possible to prioritise pathways as it will allow the assessment of which ones deserve greater attention in a given area or timeframe.

Pathway analysis and prioritisation

Addressing the important pathways of introduction and/or spread is key to tackle the introductions and spread of invasive alien species.

The systematic examination of the various routes through which alien species are introduced or spread, helps to clarify which human activities have caused the introduction. The analysis can focus on pre-border (pre-invasion) or post-border pathways of introduction or spread.

Pathways of introduction can change over time, with new pathways created, for instance, because of new trade patterns, new transport routes, altered human activities, climate change, seasonality or in response to pathway management efforts. Pathway analysis should consider a timeframe relevant for the current situation and near future and focus on active and anticipated pathways. Ideally the analysis is regularly updated to account for changes in introduction patterns.

Pathway analysis builds on the information mobilised through pathway identification for invasive alien species, including quantification of the frequency of introductions through that pathway and the volume of organisms or species it represents. The analysis can evaluate factors such as the volume of traffic along the pathway, the likelihood of known invasive species being transported along the pathway, the vulnerability of the receiving ecosystems and the potential impact of the alien species if introduced.

The analysis of pathways allows to prioritise the main routes of entry (Box 3), either by assessing the highest volume of invasive species or pathways associated with species with the greatest severity of impacts, where management interventions (such as border controls) will have the greatest chance of reducing impact or propagule pressure.

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9   IUCN. (2018). Guidance for the interpretation of the CBD categories of pathways for the introduction of invasive alien species. Technical report prepared by IUCN for the European Commission. https://op.europa.eu/en/publication-detail/-/publication/f8627bbc-1f15-11eb-b57e-01aa75ed71a1

The result can provide a basis for decision making and relevant management, possibly considering the CBD hierarchy (UNEP/CBD/COP/VI/23) where prevention is most cost-effective, followed by early detection and rapid response, followed by eradication, containment and long-term control measures. It can help identify the feasibility of targeting the riskiest pathways and select pathways that are worth being addressed by dedicated pathways action plans.

Box 3. Methods for prioritising pathways of introduction

Prioritising pathways of introduction involves the following steps:

- **Pathway identification** with quantification of the frequency of introductions through that pathway, the volume of organisms or species it represents.
- **Pathway analysis** to evaluate factors such as the volume of traffic along the pathway, the likelihood of known invasive species being transported along the pathway, the vulnerability of the receiving ecosystems and the potential impact of the alien species if introduced.
- **Pathway prioritisation** based on their potential contribution to the introduction and spread of problematic alien species and the feasibility of their management.

Case study

In accordance with Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014, on the prevention and management of the introduction and spread of invasive alien species, EU Member States are required to carry out detailed analyses of the pathways of unintentional introduction to their territories. The purpose of these analyses is to identify those pathways which require priority action, due to either the volume of species or the potential damage caused by the IAS entering the Union through them. Based on the result of these analyses, Member States are also required to establish and implement one single action plan or a set of action plans to address the priority pathways identified. Action plans are expected to describe the measures to be adopted and, as appropriate, voluntary actions and codes of good practice. The action plans for pathways developed by EU Member States are available in the Eionet Central Data Repository https://cdr.eionet.europa.eu.

ANNEX I

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 (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

The full toolkit developed to support Parties in the implementation of Target 6 can be accessed here
www.cbd.int/invasive/cbdtoolkit

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