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Working paper on feasibility of an indicator on IAS pathways

Wolfgang Rabitsch and Sophie Condé

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Authors' affiliation:

Wolfgang Rabitsch, Umweltbundesamt (AT)
Sophie Condé, Muséum national d'Histoire naturelle (FR)

EEA project manager:

Katarzyna Biala, European Environment Agency (DK)

ETC/BD production support:

Muriel Vincent, Muséum national d'Histoire naturelle (FR)

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European Topic Centre on Biological Diversity
c/o Muséum national d'Histoire naturelle
57 rue Cuvier
75231 Paris cedex, France
Phone: + 33 1 40 79 38 70
E-mail: etc.biodiversity@mnhn.fr
Website: http://bd.eionet.europa.eu/

Feasibility of an indicator on (I)AS pathways

One of the most important types of information in the practical approach to prevention and management of biological invasions is the identity of the pathways of introduction and details of the vectors.
Invasive Alien Species Pathway Management Resource

1. Introduction

1.1. What are IAS?

The recent EC proposal for a Regulation on the prevention and management of the introduction and spread of invasive alien species (EC 2013) provides definitions for alien species and invasive alien species (Article 3):

> Alien Species (AS) *means any live specimens of species, subspecies or lower taxon of animals, plants, fungi or micro-organisms introduced outside its natural past or present distribution; it includes any part, gametes, seeds, eggs, or propagules of such species, as well as any hybrids, varieties or breeds that might survive and subsequently reproduce*
>
> Invasive alien species (IAS) are *alien species whose introduction or spread has been found, through risk assessment, to threaten biodiversity and ecosystem services, and that may also have a negative impact on human health or the economy*

These definitions are widely accepted, however, it should be mentioned that there is a long history of alien definitions (that will not be repeated here) and that some of the problems in comparing different data sources results from the fact that authors define and use those terms differently. The CBD-definition of AS is similar, but IAS are defined in a more ecological context, without considering economic impacts (Box 1).

> **Box 1 CBD definitions of alien species (COP6, decision VI/23)**
>
> *Alien Species*: a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce
>
> *Invasive Alien Species*: an alien species whose introduction and/or spread threaten biological diversity.

Terminological issues are crucial for the purpose of building a trend indicator on alien species total numbers or pathways or any other aspect of biological invasions over time. Both, pathway indicators on AS and IAS, merit attention and can deliver useful results. Data need to be standardized or harmonized, at least at some least common denominator. This is true not only if different data sources (databases) are used, but also (and even more so) when different authors feed data into a database. The latter often is the case in species-rich groups with different experts for each group, e.g. spiders and ants, or even within some groups, e.g. hemiptera suborders or beetle families.

1.2. What are IAS pathways?

The recent EC proposal for a Regulation on the prevention and management of the introduction and spread of invasive alien species (EC 2013) provides a definition for alien species pathways (Article 3):

> pathways *means the routes and mechanisms of biological invasions*

'Routes' are the ways between source and recipient location of the alien species, and 'mechanisms' are the motivations, the instruments and vectors of the translocation of a species. Similar, though slightly different, wordings are used, e.g. in the Convention on the Conservation of European Wildlife and Natural Habitats: 'The geographic route by which a species moves outside its natural range (past or present); the corridor of introduction (e.g. road, canal, tunnel); and/or the human activity that gives rise to an intentional or unintentional introduction.' (Genovesi & Shine 2003).

Biological invasions are complex phenomena, so are the pathways, and there is a huge variety of terms related to the routes and mechanisms of alien species introductions. The most general and basic separation is between intentional and unintentional introduction, with the latter clearly prevailing in alien arthropods (86%, Rabitsch 2010), but not in vascular plants introduced from outside Europe (37%, Lambdon et al. 2008). In case of intentional introductions, it is usually know exactly when and where and sometimes how many individuals were introduced, whereas it is not know much about unintentional introductions. Pathway dynamics further change over time due to a change in consumer behaviour, fashion or economic trends (Nentwig 2007, Kowarik & von der Lippe 2007, Hulme et al. 2008, Rabitsch et al. 2013). Between the many different available online and printed alien species data sources, pathway terminology is not standardized. The European Network on Invasive Alien Species NOBANIS (www.nobanis.org), for example, provides a reporting tool that automatically generates pathway statistics for participating countries and the north and central European region it covers (see also Rabitsch et al. 2012a).

Carlton & Ruiz (2005) noted that the term pathway can have very different meanings in the literature, including cause, route, and the vector itself. As mentioned by Rabitsch (2010) (and others), there is some overlap (and sometimes confusion) between alien species pathways and vectors. To give an example, a man-made water channel, connecting previously isolated water catchments, is a pathway, whereas the ships and vessels travelling across natural biogeographic boundaries are vectors. Organisms may travel outside (hull fouling) or inside (ballast water) the vector using this pathway. Wilson et al. (2009) define six types of dispersal pathways, including natural dispersal mechanisms and 'introduction pathways' for human mediated translocations. Unfortunately, authors sometimes use different words for identical pathways or the same words for different pathways. If comparisons between different data sources are executed, therefore, it is of utmost importance to be clear about the sometimes subtle differences. Hulme et al. (2008) provided a pathway terminology that distinguishes between six pathway categories (Table 1).

Table 1: Pathway terminology used in Hulme et al. (2008)

Pathway	Motivation	Vectors	Examples
Release	Intentional	None	Biological Control, Game animals
Escape	Unintentional	None	Greenhouses, Botanical Gardens, Pets
Contamination	Unintentional	Ornamentals,	Stored product pests, Wood-borers,

		Fruits, Wood, Soil	Seed mixtures, Fungi on their host plants
Stowaway	Unintentional	Ships, Cars, Planes, Containers	Ballast water, Ants, Western Corn Rootworm
Corridor	Unintentional	Ships, Cars	The exodus of ponto-caspian species, horse chestnut leaf-miner
Unaided	Unintentional	None	Secondary spread from point-of-entry

In EASIN (European Alien Species Information Network, easin.jrc.ec.europa.eu), developed and maintained by JRC, the same high-level categories are used but further specified (Table 2). The 'unaided' category is skipped and 'Other' and 'Unknown' included.

Table 2: Pathway terminology used in EASIN

Pathway level 1	Pathway level 2
Release	Biocontrol
	Game animals
	Landscaping-Erosion control
	Pets, Terrarium-Aquarium species
	Other
Escape	Cultivation and Livestock
	Aquaculture
	Ornamental planting
	Use of live food-bait
	Pets, Terrarium-Aquarium species
	Zoos, botanical gardens
Contamination	Trade of contaminated commodities
	Packaging materials
	Aquaculture
Stowaway	Shipping
	Aviation
	Land transport
Corridor	Lessepsian migrants
	Inland canals
	Railroads and Highways
Other	
Unknown	

One problem with these categories is that they are not at the same degree of specialisation. Whereas 'Contaminant: Trade of contaminated commodities' includes hundreds if not thousands of species introduced as stored pests, with ornamentals, fruits and vegetables or with wood, both other 'Contaminant' categories (packing materials and aquaculture) may include just a few dozen species that utilise this particular pathway. Also, the 'Escape' category neatly distinguishes between very specific pathways. If pathway analyses are used to steer pathway management, categories should be as narrow as possible and directly related to the relevant actors executing the introduction or controls. For the above given example it

would be useful to further break down the 'Contaminant' category in EASIN into more specific pathways (Table 3).

Table 3: Suggestion for a more detailed pathway terminology at the 'Contamination: Trade of contaminated commodities' level in EASIN

Pathway level 1	Pathway level 2
Contamination	Pests of Stored Products
	Trade of ornamental plants for horticulture
	Trade of fruits and vegetables for consumption
	Trade of wood Packaging materials
	Aquaculture
	Transportation of soil
	Parasites within animals and plants
	Seed contaminant

Stowaways are species that are transported as 'blind passengers' within vehicles such as planes, cars and ships or cargo holds such as containers. The species, however, should not be attached to or be inside of some other 'material', which would make them a 'contaminant'. One of the most important stowaway pathway eventually is the translocation with ballast water across the oceans.

Corridors means if species are transported along with constructed infrastructure. As obvious this seems for aquatic species travelling in artificial canals, it may become more complicated in case of terrestrial species, moved along streets, e.g. as seeds with cars. Moreover, there is some potential overlap with both the Stowaway and the Contaminant category. If a species is translocated in the Ballast Water of a ship that uses an inland canal, is it assigned to the stowaway or to the corridor pathway category? If the seeds of a species are attached to the wheels of a car and translocated along a street, is it assigned to the contaminant or to the corridor pathway category? Assessors need to be clear about where to draw the lines between the categories. This could be achieved best by a comparative assessment of a selection of case studies by different assessors and/or a clear description of the pathways. Most online-sources do not provide much information on how they exactly define the used pathways. A detailed documentation guide would clearly help other users to compare the data.

It has to be acknowledged that the pathway for a large part of alien species is unknown, approx. 25% in the DAISIE-dataset, or 'best guess' assessments based on expert opinion, and that species may use more than one single pathway ('polyvectic', Carlton & Ruiz 2005).

Recently, the **Invasive Alien Species Pathway Management Resource** has been developed within the framework of the Global Invasive Alien Species Information Partnership (GIASIPartnership, http://giasipartnership.myspecies.info/) (co-funded from the EU) (http://acronym.co.nz:8086). Based on a prototype developed by ISSG, together with other partners (e.g. GISD, CABI-ISC, DAISIE), it aims to provide information on the identity and the management of alien species pathways that can be used by countries to develop guidelines, recommendations or risk assessments of pathways. This classification is based on the terminology used by Hulme et al. (2008) (see Table 1) and uses six main categories ('pathways') and several sub-categories that include known identified 'pathways/vectors' ('vectors/category') (Table 4), each provided with a short narrative description (particularly

useful to understand the limits of the pathways) and a list of species that are known to be introduced through this pathway, mostly retrieved from GISD (2013), but also from other source. Information is also given on legal instruments for the management of this pathway and a bibliography of relevant publications.

Table 4: Pathways and vectors/categories used in the Invasive Alien Species Pathway Management Resource.

Pathway	Vectors/Categories
Release in Nature	Acclimatisation societies
	Release in nature for use
	Biological control
	Erosion control/ dune stabilization (windbreaks, hedges…)
	Fisheries
	Hunting
	Landscape/flora/fauna improvement
	Conservation introduction
	Other intentional release (bioremediation)
	Other intentional release (reintroduction)
	Other intentional release (waste management)
Escape from confinement	Agriculture
	Aquaculture
	Botanical garden/ zoo/ aquaria
	Farmed animals, including animals under limited control (e.g. free roaming camels)
	Forestry
	Fur farms
	Horticulture
	Ornamental purpose
	Pet/ aquarium trade
	Research (in facilities)
	Other escape from confinement (fencing)
Transport – as a contaminant	Contaminant nursery material
	Contaminated bait
	Food contaminant
	Live food
	Contaminant on animals (excluding parasites and species transported by host and vector)
	Contaminant on plants (excluding parasites and species transported by host and vector)
	Organic packing material (wood packing, etc.)
	Parasites on animals (including species transported by host and vector)
	Parasites on plants (including species transported by host and vector)
	Seed contaminant
	Timber trade

	Transportation of habitat material (soil, vegetation, wood…)
Transport – as a stowaway	Container/bulk, including seafreight, airfreight, train, etc.
	Hitchhikers in or on plane
	Hitchhikers on ship/boat
	Machinery/equipment
	Angling/fishing equipment
	Military
	People and their luggage/equipment
	Ship/boat ballast water
	Ship/boat hull fouling
	Vehicles (car, train, …)
	Other means of transport
Corridor – Interconnected waterways/basins/sea	Interconnected waterways/basins/sea
Other	Ignorent Possession
	Smuggling

Why are pathways so important? They provide information to understand how alien species arrive and therefore provide leverage to respond accordingly. Beside the obvious information pathway data may deliver about their share and relevance (e.g. Table 5, Figure 1), it seems particularly useful to combine pathway data with other (I)AS data such as origin or impact. This would allow further analyses and provides deeper insight into biological invasion patterns and possible management actions. For example, Leppäkoski et al. (2002) have shown a steep increase of ponto-caspian species introduced to the Baltic Sea in the 20th century, which corresponds to the opening of canals connecting the Black Sea with the Baltic Sea (Figure 2). Pergl et al. (in prep.) analysed the relation between pathways and impacts of alien species in Europe and found that intentionally released plants were more often found to have negative impacts than expected by chance. Plants – contrary to terrestrial arthropods, mammals and fish – that use multiple pathways were found to have a greater impact than species using a single pathway.

Table 5: Pathways of the alien arthropod species in Europe according to the DAISIE-database. Due to double entries the sum differs. (Modified from Rabitsch 2010).

Pathway	Number of species	%
Released	175	10
Animal husbandry	42	2
Greenhouse escapees	204	11
Crops	70	4
Forestry	90	5
Horticultural/Ornamental	468	26
Leisure	13	1
Stored products	201	11
Stowaways	95	5
Unknown	431	24

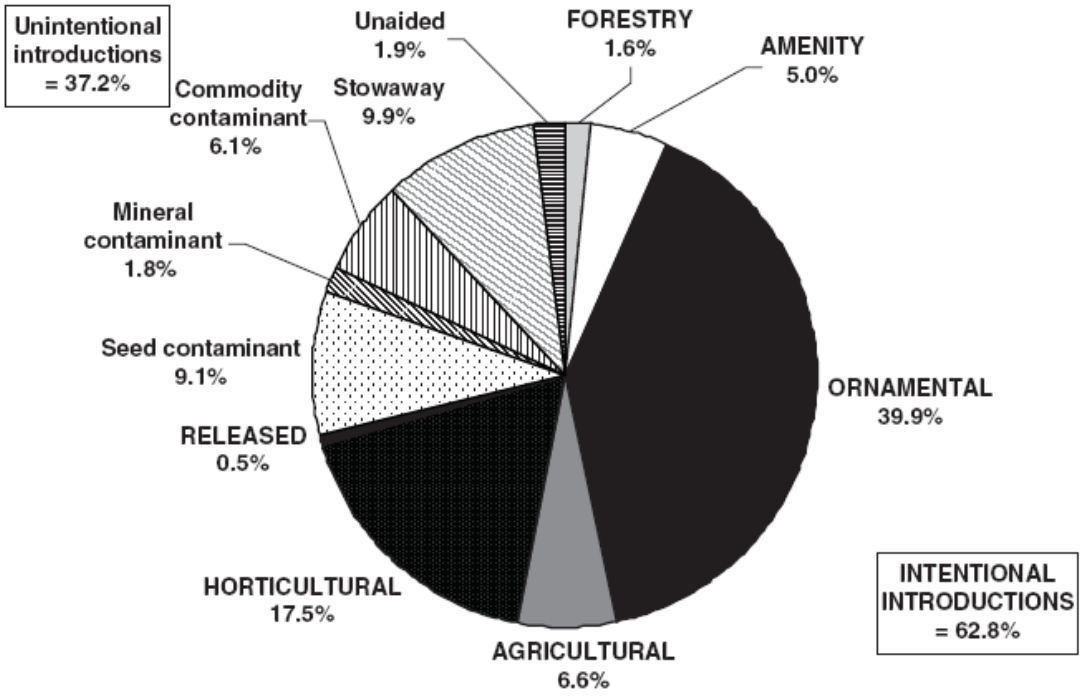

Figure 1: Relative contribution of pathways for established alien vascular plants in Europe with an origin outside Europe. (Taken from Lambdon et al. 2008).

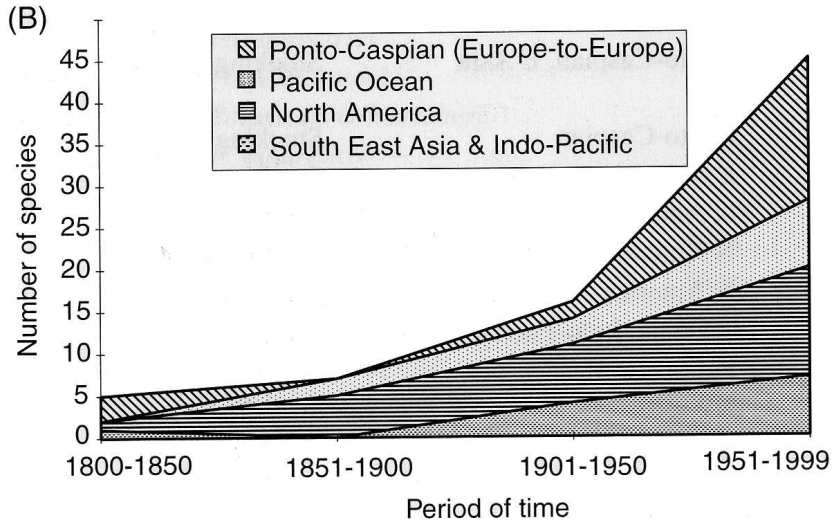

Figure 2. Chronosequence of the rate of alien species introductions into the Baltic sea from major donor areas (Taken from Leppäkoski et al. 2002).

The scale of an IAS-pathways indicator can be used to focus on regional patterns. It can be useful to have a global or EU-pathway indicator, but it may also be useful for countries or regions (e.g. islands, water catchments) to have such an indicator broken down to develop and execute more explicit management actions.

Recently, Bacon et al. (2012) evaluated the performance of existing border controls for insects in Europe and found significant gaps between the trade pathways that should be inspected and the actual number of interceptions. Many of the most likely introduction pathways yielded none or only few insect interceptions, suggesting that regular interceptions are restricted to only a too narrow range of pathways. Knowledge of such a bias is important when in comes to the prioritization of pathways for management.

1.3. The policy background of IAS pathway indicators

The importance of considering pathways in any attempt to regulate (invasive) alien species is widely acknowledged. Some policy measures are directly related to pathways, e.g. the Ballast Water Convention, International Plant Protection Convention, World Organisation for Animal Health, EU Aquaculture Regulation.

At COP10 in Nagoya, the CBD adopted its new Strategic Plan for Biodiversity 2011–2020, and a set of targets (Aichi targets), including Target 9 on alien species: 'By 2020, invasive alien species and pathways are identified and prioritised, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.' The AHTEG on indicators for the Strategic Plan for Biodiversity 2011–2020 recommended establishing (among others) an indicator on 'Trends in IAS pathways management'. Within the 'EU Biodiversity Strategy 2020' (EC 2011), Target 5 states that

> 'By 2020, Invasive Alien Species and their pathways are identified and prioritized, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS.'

Within the pan-European SEBI 2010 process ('Streamlining European Biodiversity Indicators') no specific 'pathway indicator' was developed, but subsequent work suggested working on such an indicator, as an amendment to the 'cumulative number of alien species'-indicator and to align with targets of new policy instruments (Rabitsch et al. 2012b, see further below).

1.4. Action plans on the pathways of IAS

The recent EC proposal for a Regulation on the prevention and management of the introduction and spread of invasive alien species (EC 2013) calls for a detailed analysis of pathways of IAS by each Member State (Article 11):

> Action plans on the pathways of invasive alien species
>
> 1. Member States shall … carry out a comprehensive analysis of the pathways of unintentional introduction … and identify the pathways which require priority action ('priority pathways') …
> 2. Member States shall establish and implement an action plan to address the priority pathways … include a timetable for action and … describe measures …
> 3. The action plan shall include measures … based on cost-benefit-analysis …
> (b) … to minimise contamination by IAS of goods and commodities, and any vehicle and equipment,
> (c) … to ensure appropriate checks at the Union borders,
> (d) … of the International Convention for the Control and Management of Ships Ballast Water and Sediments

Within 18 months of the enforcement of the Regulation Member States have to submit an in-depth analysis of the pathways of unintentional introduction including a prioritization which pathways require action ('priority action'). It is, however, unclear if and how this relates to pathways of intentional introductions (e.g. horticultural, ornamental and animal trade) that also require action.

After three years the Action Plan should be implemented and measures to address the priority pathways adopted to prevent unintentional introductions. The Action Plan then is foreseen to be adjusted every four years.

Depending on the detailed measures and activities initiated within this Action Plan useful data on the quality and quantity of unintentionally introduced alien species may emerge and used to build an indicator over time. However, this is difficult to foresee as long as no details on the Action Plans are available. Ideally, national data on the priority pathways of unintentional introductions accumulate that can be aggregated at the EU level in regular intervals. If counter-measures related to the priority pathways are successful, the indicator should be able to demonstrate a decrease in the numbers of unintentionally introduced alien species.

2. Pathway data and the way forward?

The recently established COST Action TD1209 'ALIEN Challenge' (http://www.brc.ac.uk/alien-challenge) aims to facilitate knowledge gathering and data sharing through a network of experts that provide support to a European IAS information system (EASIN) that should inform decision-makers. It aims to identify needs and formats for AS information by different user groups and specifically for implementation of the EU 2020 Biodiversity Strategy. Working Group 2 will explore approaches to analyse trend data in relation to pathways.

As demonstrated in the previous sections there is great diversity in pathway data in existing alien species databases. An attempt to harmonize different classifications was made by the GIASIPartnership within the Invasive Alien Species Pathway Management Resource (http://acronym.co.nz:8086). This useful attempt may need futher discussion, e.g. within the ALIEN Challenge community, but if it is widely accepted, it would be useful to adapt existing data collections or adapt alien species data in the EASIN system. A drawback of the former would be that many people need to be involved and potential confusion in the assessment of categories may be the result. On the other hand, local knowledge may be incorporated, which otherwise may get lost. A drawback of the latter would be that local information may get lost and data entries may differ between the local database and EASIN. The advantage would be that few persons assess the pathways and assessor-based variability is reduced.

Rabitsch et al. (2012a, 2012b) provided an overview and discussion on the obstacles that prevent a straightforward development of a trend indicator on pathways with currently available data. They criticized the lack of a standardized terminology for pathways. DAISIE-data were used to demonstrate trends in the most important pathways of alien terrestrial arthropod species over time (Figure 3). The cumulative presentation indicates that whereas numbers of introduced stored product pests, biological control agents and forest pests seem to level something, the numbers of species in the horticultural/ornamental trade and the number of species with unknown pathways increase exponentially. 'Unknown' here means that the specific pathway is not known, although many of these species can be assigned to a 'transport-related-pathway'.

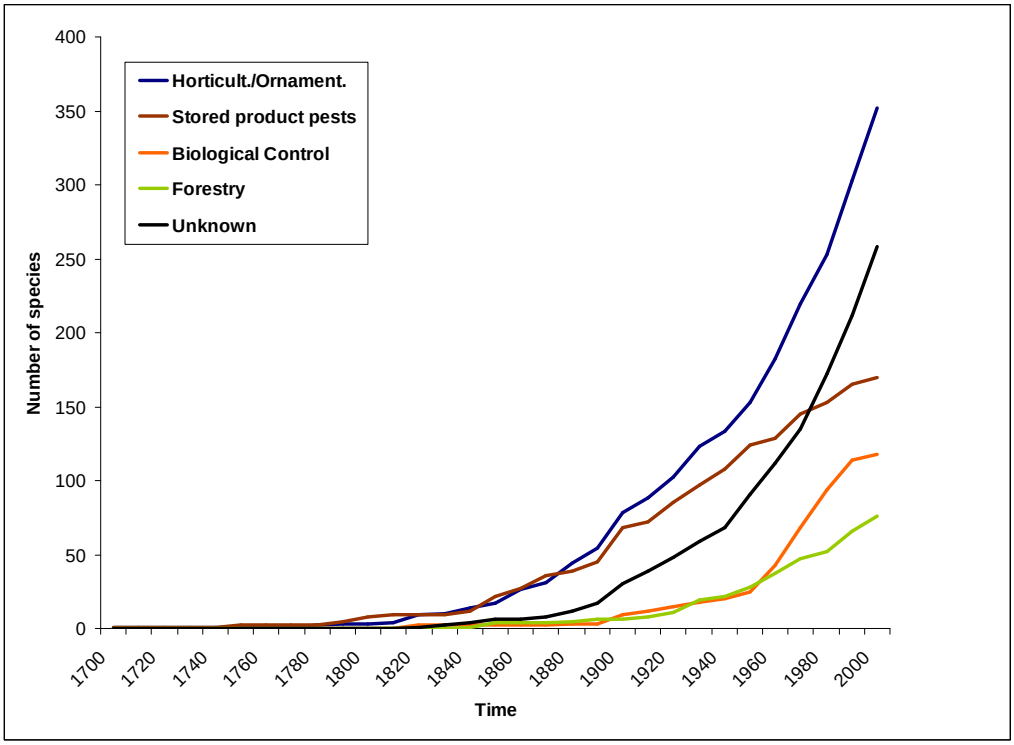

Figure 3. Temporal trends of alien terrestrial arthropod species (n=974) in Europe for different pathways of introduction. Source: DAISIE (unpubl.) (Taken from Rabitsch et al. 2012b).

4. Conclusion

Developing and establishing a pathway indicator on IAS is in agreement with current global and EU policies related to IAS management. The current COST Action ALIEN Challenge provides a unique opportunity to gather relevant data and harmonize currently existing terminologies. Based on a scientifically sound framework, it seems very feasible to develop a useful IAS-pathway indicator within the next years. It is not yet clear how the requested action plans on unintentional pathways, to be developed by Member States within the forthcoming EU regulation on IAS, will provide sound data useful for an indicator, but any guidance provided by the EC should bear in mind this potentially useful resource. This also includes harmonized terminology and consolidated data flow.

A pathway indicator can have a broad geographic (all of Europe), environment (all environments), and taxonomic (all organisms) coverage, but it can also be broken down according to particular needs. It is requested from policy strategies and easy to communicate. A disadvantage may be the sensitivity of the indicator, which may not be high enough to detect any rate of change towards the 2020 target, and may underestimate a hypothetical decrease in alien species numbers.

5. References

Bacon SJ, Bacher S, Aebi A (2012) Gaps in Border Controls Are Related to Quarantine Alien Insect Invasions in Europe. PLoS ONE 7(10): e47689. doi:10.1371/journal.pone.0047689

Carlton JT & Ruiz GM (2005) Vector science and integrated vector management in bioinvasion ecology: conceptual frameworks. In: Mooney HA et al. (eds) Invasive alien species. Island Press, Washington, pp 36-58.
EC (2011) Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions 'Our life insurance, our natural capital: an EU biodiversity strategy to 2020'. COM(2011) 244 final, Brussels, 3.5.2011, 17 pp.
EC (2013) Proposal for a Regulation of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species. COM(2013) 620 final, Brussels, 9.9.2013, 36 pp.
Genovesi P & Shine C (2003) Final version. Standing Committee 23rd meeting, Strasbourg, 1-5 December 2003. T-PVS (2003) 7 revised. Council of Europe, Strasbourg, France.
GISD (2013) Global Invasive Species Database (http://www.issg.org/database/welcome/)
Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Solarz W & Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. J. Appl. Ecol. 45: 303-341.
Kowarik I & von der Lippe M (2007) Pathways in plant invasions. In: Nentwig W (Ed) Biological Invasions. Springer, Berlin, 29-47.
Lambdon P et al. (2008) Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia 80: 101-149.
Leppäkoski E, Olenin S, Gollasch S (2002) The Baltic Sea: a field laboratory for invasion biology. In: Leppäkoski E, Olenin S, Gollasch S (eds) Invasive aquatic species of Europe: distribution, impacts and management. Kluwer, Dordrecht, pp. 253-259.
Nentwig W (2007) Pathways in animal invasions. In: Nentwig W (Ed) Biological Invasions. Springer, Berlin, 11-27.
Rabitsch W (2010) Pathways and vectors of alien arthropods in Europe. BioRisk 4: 27-43.
Rabitsch W, Essl F, Genovesi P & Scalera R (2012a) Invasive alien species indicators in Europe - a review of Streamlining European Biodiversity (SEBI) Indicator 10 EEA-Technical Report, 15/2012, 48 pp.
Rabitsch W, Essl F, Genovesi P & Scalera R (2012b) Streamlining European Biodiversity (SEBI): Review and testing of methodological developments of SEBI indicator 10 — Invasive alien species in Europe. Report to the EEA, unpublished.
Rabitsch W, Milasowszky N, Nehring S, Wiesner C, Wolter C & Essl F (2013) The times are a changing: temporal shifts in patterns of fish invasions in Central European freshwaters. J. Fish Biol. 82: 17-33.
Wilson JR, Dormontt EE, Prentis PJ, Lowe AJ, Richardson DM (2009) Something in the way you move: dispersal pathways affect invasion success. Trends Ecol Evol 24: 136-144.