Supplementary material 1: Evidence used to assess the pathway frameworks

Evidence for the assessment of the framework used by the New Zealand biosecurity surveillance system

Table S1. The evidence used to assess the framework used by the New Zealand biosecurity surveillance system. Presented are the CAGED properties of pathway frameworks, the outcomes of an assessment indicating which of the five properties the framework possesses, and the evidence. Categories were partially compatible as some categories possessed the property, but not all.

Property	Outcome	Evidence
Compatibility	Partially	Some categories will not be compatible with the data that are available in some regions. The framework is compatible with the data that are available in New Zealand, which has one of the best biosecurity systems in the world, and where interceptions are meticulously recorded (Ministry of Agriculture and Forestry (MAF) Biosecurity New Zealand 2008). However, in other regions, such as South Africa where interception data are not readily available (Faulkner et al. 2017), it is often not known whether a species has been intentionally imported through the mail or through other processes.
Actionability	Yes	The categories of the framework were developed in the context of at-border interventions and the links between the categories and the location of these interventions are clear (Figure S1).
Generality	No	The framework does not make provision for introductions where alien species spread through natural dispersal over land borders, and the 'sea' and 'air' categories are only applicable to certain regions, taxa or habitats (see Table S2). The categories are inclusive and so it is likely that it will be possible to integrate data for current and historical pathways as well as those that will develop in the future.
Equivalency	No	Categories are subsets of other categories. For example, goods can be imported through the mail and, therefore, the 'mail' category is a subset of the 'imports' category.
Distinctness	Yes	Assessment made by the authors based on information on the framework (see Ministry of Agriculture and Forestry (MAF) Biosecurity New Zealand 2008) and knowledge of pathways of introduction.

Table S2. The six categories of the pathway framework used by the New Zealand biosecurity surveillance system, and details on the regions, taxa and habitats for which the categories are applicable.

Category	Region	Taxa	Habitat
Imports	All	Invertebrates, vertebrates and plants (e.g. imported pets and plants, and insects and seeds in containers)	Terrestrial, freshwater and marine (e.g. terrestrial species imported for horticulture, marine or freshwater species imported for the aquarium trade)
Vessels	All	Invertebrates, vertebrates and plants (e.g. rodents that stowaway on vehicles, hull fouling invertebrates, and seeds on vehicle's tyres)	Terrestrial, freshwater and marine (e.g. rodents on vehicles, freshwater species on the hulls of ships, and marine species in ballast water)
Passengers	All	Invertebrates, vertebrates and plants (e.g. eggs of pet birds in luggage, invertebrates on fruit in luggage, and seeds in luggage)	Terrestrial, freshwater and marine (e.g. seeds in luggage, eggs of freshwater and marine pets in luggage)
Mail	All	Invertebrates, vertebrates and plants (e.g. pet reptiles and invertebrates, and seeds of garden plants)	Terrestrial, freshwater and marine (e.g. pet reptiles, and freshwater and marine plants for aquaria)
Sea	Only countries with a sea border. Not applicable to landlocked countries	Invertebrates, vertebrates and plants (e.g. marine fish, invertebrates or plants that naturally disperse from their introduced range)	Terrestrial and marine (e.g. insects transported passively on floating wood, and marine invertebrates with planktonic larvae). Not applicable for freshwater species
Air	All	Invertebrates, vertebrates and plants (e.g. birds, insects or plants that naturally disperse from their introduced range)	Terrestrial (e.g. seeds blown by the wind). Not applicable for freshwater or marine species

Pathway	Location of interventions
Imports	Transitional facilities
Vessels	Airports and seaports
Passengers	Airports and seaports
Mail	Mail centre
Air	Air border
Sea	Marine border

Figure S1. The six categories of the pathway framework used by the New Zealand biosecurity surveillance system, and the location of the interventions for each category (Ministry of Agriculture and Forestry (MAF) Biosecurity New Zealand 2008). The locations within airports and seaports where interventions take place will differ for vessels and passengers.

Evidence for the assessment of the main categories of the CBD framework

Table S3. The evidence used to assess the main categories of the CBD framework. Presented are the CAGED properties of pathway frameworks, the outcomes of an assessment indicating which of the five properties the categories possess, and the evidence.

| Property	Outcome	Evidence
Compatibility	Yes	Compatibility does not appear to have been an issue in studies that have used the categories (e.g. Pyšek et al. 2011, Faulkner et al. 2016, Pergl et al. 2017).
Actionability	Yes	The categories were developed to inform existing regulatory instruments and the links between the categories and regulations are clear (Figure S2).
Generality	Yes	The categories were developed with universality in mind (Hulme et al. 2008) and have been successfully used in a number of published assessments to classify pathways from different regions [e.g. South Africa (Faulkner et al. 2016) and Czech Republic (Pyšek et al. 2011)], taxonomic groups (Faulkner et al. 2016, Padayachee et al. 2017, Pergl et al. 2017) and habitats (Padayachee et al. 2017). The categories are inclusive and so it is likely that it will be possible to integrate data for current and historical pathways as well as those that will develop. We found one study, a horizon scanning exercise (Matthews et al. 2017), where a category called 'other' was used instead of 'unaided'. This 'other' category was only used for a few macroinvertebrates, and this issue does not appear to be prevalent.
Equivalency	Yes	None of the categories is a subset of another category.
Distinctness	Yes	Published assessments that have used the categories have not indicated that they are ambiguous. Furthermore, when implementing the categories in published assessments (e.g. Faulkner et al. 2016), the authors found them to be distinct.
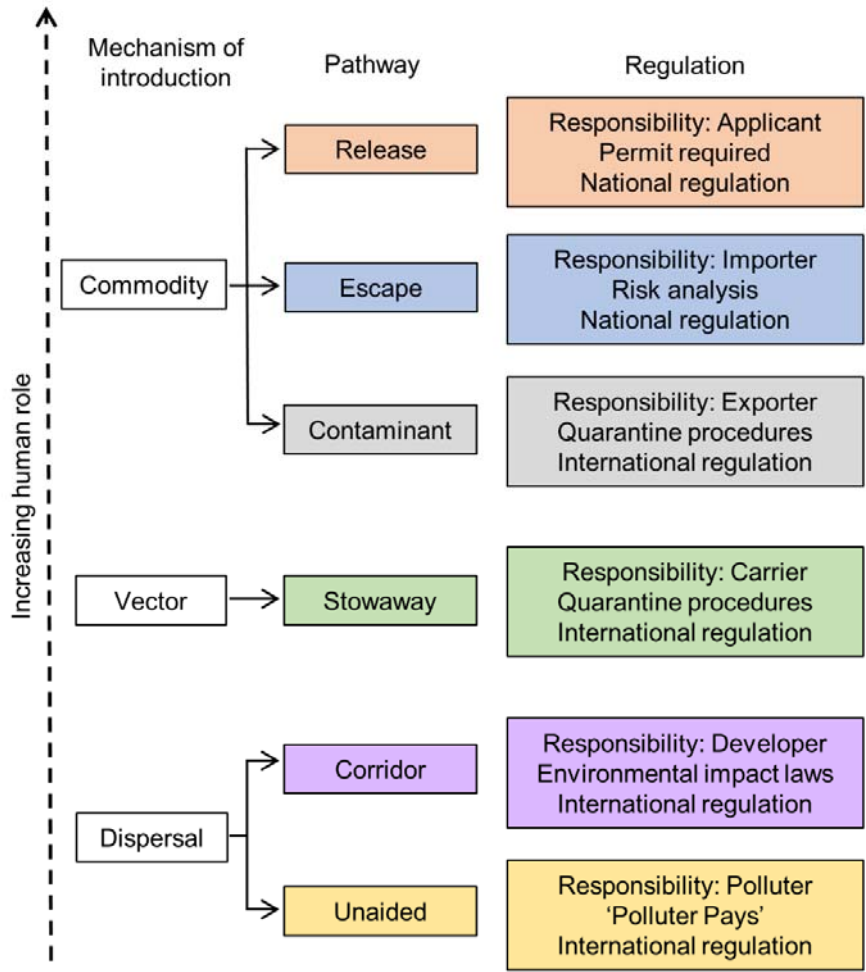
Figure S2. The pathway classification framework developed by Hulme et al. (2008). The framework recognises that an organism can be introduced to a new region through three mechanisms of introduction (the importation of a commodity, the arrival of a transport vector and the natural dispersal of an alien species) and that these mechanisms are associated with six pathway categories. The regulatory methods that are used to manage each pathway are shown. The six categories of this framework form the main categories of the framework adopted by the CBD.
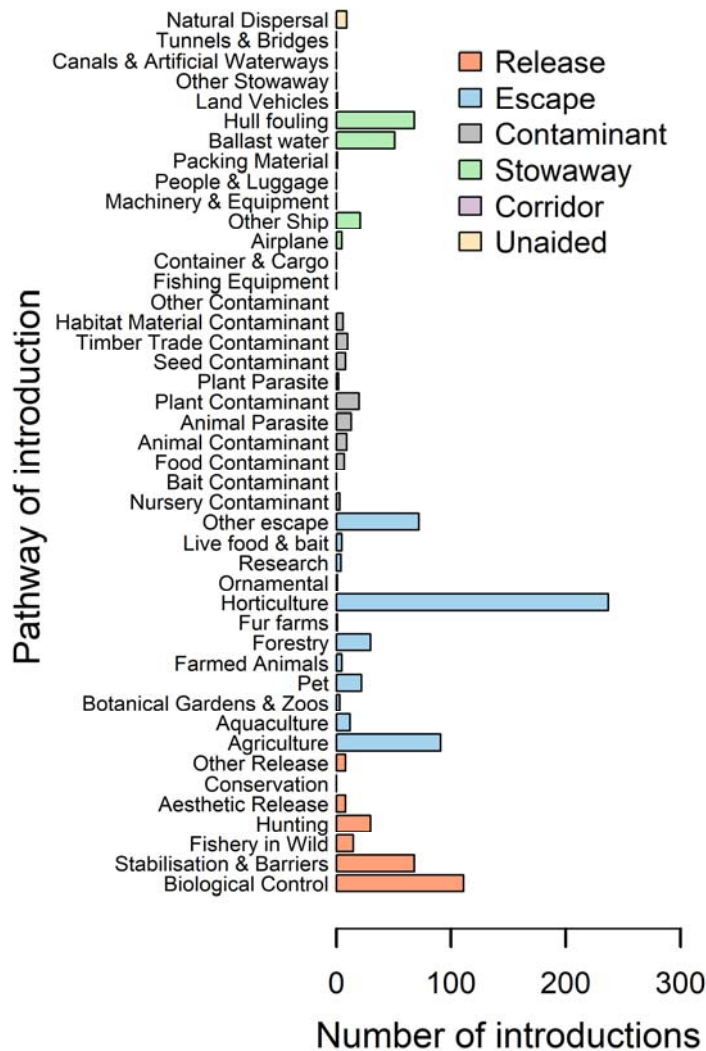
Figure S3. The number of taxa introduced to South Africa through the pathways of introduction, as classified using the sub-categories of the CBD framework. Most introductions are only through a few sub-categories, with many sub-categories having no introductions. For many alien taxa in South Africa pathway of introduction data is not available. Data from van Wilgen and Wilson (2018).

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