Tackling Invasive Non-Native Species in the UK Overseas Territories

Pathway Analyses

Dr Jill Key, March 2018

Acknowledgements

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Executive summary

- Pathway analysis was carried out for a total of 2,629 introductions across 15 UK Overseas Territories (OT) as input to a biosecurity horizon scanning exercise; it was not done for the Cyprus Sovereign Base Areas as horizon scanning was done in April 2017 as part of a Darwin Plus project.
- 'Pathways' is defined as the routes and mechanisms of the introduction and spread of invasive alien species.
- The analysis has three elements:
    - Connectivity of the OT: volume, frequency and origin of sea and air transport networks
    - Exotic animal and plant ownership
    - Pathways of introduction of existing non-native species
- For each OT a checklist of existing non-native species was put together from available sources. Parameters for inclusion are:
    - Records from 1980 onwards to exclude historic pathways.
    - All non-native species, not just invasive.
    - Confirmed identification to the species level.
    - Terrestrial species.
- Pathways were inferred for non-native species using the pathway classification adopted by the Convention on Biological Diversity SBSTTA 18, distinguishing intentional and unintentional introductions at the category and subcategory level.
- The greatest number of introductions was of plants (1,515 introductions, 58%) then invertebrates (1,030 introductions, 39%) and finally vertebrates 984 introductions, 3%).
- Overall, 71% of non-native plant species result from intentional introductions, primarily introduced through the horticulture trade as garden plants.
- Overall, 97% of non-native invertebrate species result from unintentional introductions, with 77% of these as transport contaminants and 23% as transport stowaways. The commonest transport contaminant pathway was of live plant material.
- Overall, 58% of non-native vertebrate species result from intentional introductions (release in nature plus escape from confinement), primarily through the pet trade.
- In terms of the geographic origin of non-native species, the commonest was “widespread” with 66% of records.
- Interception data was available for eight of the 15 Territories but is of varying quality as it is formally only collected by one. Available data confirms the association of certain species with fresh produce.
- In conclusion, the most risky pathway for introducing new species of non-native plant and invertebrate species is the intentional importation of live plants, from the point of view of the plant itself as a potential weed, and as a vector for contaminants such as invertebrates.
- Associated material such as soil and plant pots with imported garden plants increase the risk of the horticulture pathway.
- For vertebrates, the pet trade stands out as the most risky pathway of introduction.
- Not included in the analysis is the confidence level with which any one species was assigned to a pathway.

- A measure of the impact (invasiveness) of introduced non-native species was also not included in the analysis. It is therefore not possible to determine if some pathways are more likely to introduce more harmful species.
- Conclusions drawn at the higher category level are more robust than those at the lower subcategory level.

General introduction and methods

Introduction

A gap analysis of biosecurity capacity and practices in the UK Overseas Territories (OTs) carried out in early 2017 found that the main gaps occurred in the area of prevention, and recommended priority capacity building needs included addressing “the fundamental areas of horizon scanning, pathway analysis and risk assessment, in order to provide the information necessary to develop a cost-effective biosecurity strategy appropriate to each territory’s needs”. A programme of horizon scanning is planned, and with preliminary pathway analysis to provide input to each exercise.

'Pathways' is defined as the routes and mechanisms of the introduction and spread of invasive alien species (Regulations (EU) no. 1143/2014, Art. 3).

The preliminary analysis is a desk study with the aim of identifying:

1. Connectivity of the OT: volume, frequency and origin of sea and air transport networks
2. Pathways of introduction of existing non-native species

As escape from confinement has been found to have the highest number of introductions globally and in Europe, this is also identified:

3. Exotic animal and plant ownership

Note that historic pathways of introduction can almost never be known, only inferred, and in the relatively short time available for this desk-study a number of assumptions had to be made.

This report covers the methods used for preliminary pathway analysis of 15 OTs: Anguilla, Ascension, Bermuda, British Antarctic Territory, British Indian Ocean Territory, British Virgin Islands, Cayman Islands, Falkland Islands, Gibraltar, Montserrat, Pitcairn, St Helena, South Georgia and the South Sandwich Islands, Tristan da Cunha and Turks and Caicos Islands. The Cyprus Sovereign Base Areas are not included as horizon scanning was carried out in April 2017 as part of Darwin Plus project DPLUS056.

Methods

Connectivity

Information for connectivity and visitor statistics were sourced from individual OT tourist and government websites, airline websites, and government statistics offices, as well as by consultation with contacts in each OT. In addition, general information can be found in the following sites:

- https://www.cruisetimetables.com/ Global information on cruise timetables
- http://caribya.com/ General information on travel and connections in the Caribbean OTs and independent states.

Additional sources used for each OT are given in the relevant results report.

Pathway of introduction for existing non-native species

For each OT a checklist of existing non-native species was put together from available sources as follows:

- RSPB stocktake database (Churchyard et al 2014)
- CABI Invasive Species Compendium
- Existing databases for each Territory, where available.
- Existing regional databases, where available

Details of Territory and regional databases are given in the relevant results reports.

Parameters for inclusion in the checklist are as follows:

- Records from 1980 onwards. Note that "first record" doesn't necessarily equal the date of first arrival, just the first time the species is officially recorded and in many cases will be an artefact of the intensity and location of sampling.
- All non-native species are included, not just species listed as invasive or pests in the agricultural, environmental and public health context. In some cases this will include species which are present only in confinement and also species which are considered unlikely to escape into the wild.
- Only records with confirmed identification to the species level.
- Only terrestrial species are considered here.

Note that for the sake of simplicity Collembola, the springtails, are categorised as Insects and not the modern classification Entognatha.

For each species, the most likely pathway of introduction was inferred. The categorisation of pathways for the introduction of alien species is taken from the Convention on Biological Diversity SBSTTA 18 classification (UNEP/CBD/SBSTTA/18/9/Asdd.1). Introductions can be intentional or unintentional:

- Intentional introductions:
    - Release into nature
    - Escape from confinement
- Unintentional introductions:
    - Transport contaminant
    - Transport stowaway

In addition, introductions can be via corridors (for example interconnected waterways) and unaided secondary dispersal across borders.

Within these categories there are a number of subcategories which for the purposes of this report have been defined as shown in Table 1. Note that this table only includes the sub-categories relevant to the species analysed during this pathway analysis.

Table 1. Definitions of pathways of introduction on non-native species

Category	Subcategory	Details
Release in Nature	Biological control	Biological control agents (eg Insect parasitoids, ladybirds, etc)
	Erosion control/ dune stabilization	For windbreaks, hedges, dune stabilisation (eg Casuarina)
	Hunting	Sport hunting Animals used for hunting (e.g. ferret) as well as quarry

	Landscape/flora/fauna “improvement” in the wild	To purposefully change species composition in the wild (eg species introduced by acclimatisation societies)
Escape from Confinement	Agriculture (including Biofuel feedstocks)	Food crops Orchard crops (fruit, nuts, coffee) Pasture grasses Livestock bred as food Biofuel Agroforestry
	Botanical garden/zoo/aquaria (excluding domestic aquaria)	Public and private collections of exotic animals and plants, held in cages or pinioned
	Pet/aquarium/terrarium species (including live food for such species)	Domestic animals, small furries Cage birds, parrots Reptiles and amphibians Goldfish, koi, guppies, etc Stick insects, spiders, scorpions, etc. Daphnia, bloodworms, Artemia, cockroaches
	Forestry (including afforestation or reforestation)	Timber, forestry
	Horticulture	Garden plants Medicinal plants Herbs Floriculture
	Ornamental purpose other than horticulture	Amenity planting (e.g. planting in parks, golf courses, street trees, etc). Bark for tapa cloth Wildfowl collections Deer parks
Transport - Contaminant	Contaminant nursery material	In soil associated with live plants, eg springtails, nematodes, many insects with soil borne eggs, plant seeds if species are associated with nurseries
	Food contaminant (including of live food)	Fresh produce (fruit and vegetables) Stored produce (beans, cereals, flour etc) Dried meat, biltong
	Contaminant on animals (except parasites, species transported by host/vector)	Plant seeds on animal fur or feathers Species associated with bee hives eg wax moths
	Parasites on animals (including species transported by host and vector)	Ticks, fleas, mites Intestinal worms Insect parasitoids (not intentionally introduced as biocontrol agents)
	Contaminant on plants (except parasites, species transported by host/vector)	Live plant material: leaves, stems, trunks, twigs, roots, bulbs, etc. (eg Species associated with live plant material, so primarily invertebrate plant pests, eg Hemiptera,Lepidoptera, thrips, mites)
	Parasites on plants (including species transported by host and vector)	Fungi Pathogens
	Seed contaminant	Bird seed Animal feed Seeds for planting (eg Mainly annual weeds and grasses in with commercial seeds or cereal grains; invertebrates which live inside grains/seeds at some stage in their life)
	Timber trade	Green timber, newly cut wood Dried timber
	Transportation of habitat material	Compost Topsoil Hay, straw, bedding Wood chips and shavings Aggregate, sand, gravel
	Angling/fishing equipment	Commercial scale

Transport - Stowaway	Container/bulk	Shipping containers (inside and out) and their contents – including household goods, personal goods, construction and building materials, used tyres, etc. Break bulk General “cargo” (eg many generalist crawling species such as wolf spiders, ground beetles, ants, geckos)
	Hitchhikers in or on airplane	(eg Mostly aerial insect vectors)
	Hitchhikers on ship/boat (excluding ballast water and hull fouling)	Cargo vessels Cruise ships Ships Ferries Yachts Recreational vehicles Other vessels such as oil rigs, barges (eg Mostly generalists such as orbweb spiders, and aerial insect vectors)
	Machinery/equipment	Farming equipment Road mending equipment Construction equipment Aquaculture equipment Aquaria equipment Pumps (eg .Mostly plant seeds of small annual species and grasses likely to be stuck in mud, plus generalist crawling insects associated with farms, waste land)
	People and their luggage/equipment (in particular tourism)	Shoes, boots, golf shoes Velcro fastenings Luggage = suitcases Golf bags Dive gear Sports gear Angling equipment (personal scale)
	Organic packing material, in particular wood packaging	Shipping pallets, treated and untreated Cardboard boxes Wood straw
	Vehicles (car, train, …)	Compacted mud Inside vehicles, wing mirrors, other spaces (eg. Plant seeds stuck in mud on cars, trucks etc., generalist invertebrates, spiders etc)
Corridor	Marine currents	(eg sea pea, beach naupaka)
Unaided	Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5	Wind currents (eg seeds of monk orchid)

Pathway of introduction was inferred as follows, in broadly hierarchical order:

- Pathway recorded for the species in that Territory.
- Pathway recorded for the species in another Territory or location.
- Pathway examples included in the published species account.
- Pathway examples included in databases such as the CABI Invasive Species Compendium and Global Invasive Species Database.
- Where there was no data at the species level, information at genus or family level was searched to determine broad life history and ecological trends and from this, infer the most likely pathway.
- Where there is no other data, apply generalisations developed in consultation with experts (see below and Table 2).

Examples of useful sites consulted extensively during this work are given below.

For invertebrates:

- http://srs.britishspiders.org.uk/portal.php/p/Welcome. Information on spiders and harvestmen in Britain, including habitat and field layers where they occur.
- http://bugguide.net/node/view/15740. Information on insects, spiders and other invertebrates in the United States & Canada.
- http://www.padil.gov.au/. Datasheets from the Australian government, including commodities on which specimens have been intercepted.
- http://www.antwiki.org/wiki/Welcome_to_AntWiki. Information on ants.
- http://diptera.myspecies.info/. Information on Diptera (flies).

For plants:

- http://tropical.theferns.info/. The useful tropical plants database.
- http://www.plantwise.org/KnowledgeBank/. Information from Kew Gardens.

Except where specific information exists, assumptions as to the most likely pathway have been made using generalisations as shown in Table 2 for various taxa. One source of information for the generalisations was the detailed summary of all possible pathways of introduction of various taxa into St Helena developed by Dr R. Key during the production of this report, see Annex 1.

Where it was not possible to infer a single most likely pathway, multiple pathways were scored, giving each possible pathway the same score of 1. It was assumed that the inferred pathway for any one species would be same regardless of which Territory it had been introduced to, except where there is documented evidence to the contrary, for example the giant taro *Alocasia macrorrhiza* was most likely to have been introduced for agriculture in Pitcairn as it is a common food in Polynesia, but as a garden plant in other Territories lacking a Polynesian culture.

Table 2. Most likely pathways for a range of taxonomic groups of terrestrial invertebrate species.

Taxonomic group	Most likely pathway
Nematodes	Transport contaminant: live plants and associated soil, nursery material, habitat material.
Woodlice	Transport contaminant: live plants and associated soil, nursery material, habitat material.
Gastropods	Transport contaminant: live plants and associated soil, nursery material, habitat material. Transport stowaway: shipping containers
Oligochaetes	Transport contaminant: live plants and associated soil, nursery material, habitat material.
Centipedes (Geophilomorpha)	Transport contaminant: live plants and associated soil, nursery material, habitat material.
Millipedes	Transport contaminant: live plants and associated soil, nursery material, habitat material. Transport stowaway: shipping containers
Springtails	Transport contaminant: live plants and associated soil, nursery material, habitat material.
Earwigs, *Pheidole* ants, Hemiptera, leaf eating beetles	Transport contaminant: live plants.
Predatory beetles and detritivores	Transport stowaway: shipping containers
Lepidoptera	Transport contaminant: fresh produce
Spiders	Transport stowaway, with house and hunting spiders associated with more commodities than web weavers
Monomorium ants, termites, wood-boring beetles	Transport stowaway: shipping containers, wooden materials
Solitary bees, eg *Hylaeus* species	Transport stowaway: shipping containers (with eg organic packing materials, ornamental straw products, etc.)
Parasitic wasps	With the host.
Plant seeds of small annual species	Transport contaminant of seeds, possibly also of habitat material (soil, vegetation)

Recent interceptions

In addition to the checklist of existing non-native species, the same exercise was also done with data from interceptions where available. In this case the actual pathway is known. Data was available for eight of the Territories: Ascension Island, Bermuda, British Indian Ocean Territory, Cayman Islands, Falkland Islands, St Helena, Tristan da Cunha, and Turks and Caicos Islands.

Source of non-native species

The current geographic distribution of species in the checklist was categorised from the point of view of where the species could have entered the pathway. The internet was mined for the most up-to-date distribution data, commonly accessed sites being:

- CABI Invasive Species Compendium http://www.cabi.org/isc/

- Encyclopaedia of Life http://eol.org/
- Catalogue of Life http://www.catalogueoflife.org/

The source of intentionally introduced biocontrol agents is not included in this part of the analysis.

Exotic animal and plant ownership

Information for exotic animal and plant ownership and sales were sourced via a general internet search and also generally from:

- Zoos Worldwide http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- Botanic Gardens Conservation International http://www.bgci.org/

Additional sources used for each OT are given in the relevant results report.

Process applied for this analysis

Contacts established during the biosecurity gap analysis carried out in early 2017 were closely involved in the development of each Territories report.

A draft report was developed for each OT and shared as widely as possible within each one. Feedback was incorporated and drafts revised until final approval was given by the OT that the report accurately reflects the situation and most likely pathways, as far as is known.

The results for each OT are presented separately and designed to be accessible independent of each other, together with this general methods section, for the taxonomic experts who will be carrying out the horizon scanning exercises for each Territory. A general results and discussion section is also available separately, giving an overview of the results across all 15 OTs.

Caveat

It is important to note that time was limited for the completion of this pathway analysis and a "quick and dirty" approach was taken, with a focus purely on providing input to horizon scanning exercises; results should be interpreted accordingly.

General references

Churchyard, T., Eaton, M., Hall, J., Millett, J., Farr, A., Cuthbert, R. and Stringer, C. (2014). The UK's wildlife overseas: a stocktake of nature in our Overseas Territories. Sandy, UK: RSPB.

Hulme P. E., Bacher S., Kenis M., Klotz S., Kühn I., Minchin D., Nentwig W., Olenin S., Panov V., Pergl J., Pysek P., Roques A., Sol D., Solarz W. and Vilà M. 2008. Grasping at the routes of biological invasions: a framework for integrating pathways into policy. Journal of Applied Ecology 2008, 45, 403–414 doi: 10.1111/j.1365-2664.2007.01442.x

Anguilla

Executive summary

- Anguilla primarily has direct connections within the Caribbean region, plus the USA.
- Pathway analysis was done for 137 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- The pet trade is the probable source of half of the vertebrate species.
- The exotic pet trade is not considered particularly important for Anguilla.
- For plants, escape from confinement was the commonest pathway of entry.
- Most introduced species are not confined to the region and have a widespread geographic distribution, suggesting that global trade is more important than local trade.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Erosion control/ dune stabilization			*
	Landscape/flora/fauna “improvement”	*		
ESCAPE FROM CONFINEMENT (2)	Agriculture	*		**
	Pet/aquarium/terrarium species		*	
	Forestry			*
	Horticulture			***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*	*	*
	Food contaminant (including of live food)	*		*
	Parasites on animals	*		
	Contaminant on plants	*		
	Seed contaminant	*		**
	Timber trade	*		
	Transportation of habitat material	*	*	*
TRANSPORT – STOWAWAY (4)	Container/bulk	**	*	
	Machinery/equipment			*
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)	**		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for Anguilla.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for Anguilla by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Taxon	Total species	Non-native species
Invertebrates	147	1
Vertebrates	401	19
Plants	420	196

The quality of baseline information in Anguilla was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Some	Some

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.cruisetimetables.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- https://ivisitanguilla.com/
- http://www.gov.ai/tourism.php

Visitor statistics are sourced from:

- Government of Anguilla Statistics Department

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Broome, R, Sabir, K, Carrington, S. (2007) "Plants of the Eastern Caribbean" http://ecflora.cavehill.uwi.edu/index.html	Comprehensive, up to date in 2007
	Acevedo-Rodríguez, P. & M.T. Strong. (2007) Catalogue of the seed plants of the West Indies http://botany.si.edu/Antilles/Westindies/	Comprehensive, up to date in 2007

Results

Points of entry

Anguilla has regular direct flight connections only within the region, from Puerto Rico, St, Thomas and St. Croix (USVI), St. Maarten/Martin, USA (Private jets), St.Kitts & Nevis, St. Barths, Tortola (BVI), Antigua, Dominican Republic and Dominica. Ferry services run between Anguilla and St Maarten/Martin, with several services running daily. The journey takes around 20 minutes. Private jets arrive mainly from the USA or St. Thomas, and from Puerto Rico and USA for Medivacs.

Passenger arrival in 2016 totalled 25,817, of which 17,501 were stay-over tourists and 8,975 day–trippers on cruise ships. Sea is main mode of entry (89.8%) and the USA is the main “source market” of tourists.

There is one port of entry for yachts, Road Bay; no information was found for the number of yachts visiting Anguilla each year. Cruise ships dock at two ports of entry: Road Bay and Blowing Point.

Cargo arrives by both sea and air on a weekly basis; main ports of departure are USA, St. Maarten/St. Martin; US Virgin Islands and Dominica. Containers also arrive from Japan via USA.

Connectivity for 2016 is summarised in Table 3.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks for 2016.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship	Various	Passengers, crew	Around 25 per year	8,975 visitors
	Ferry	St Maarten/Martin	Passengers	Several services daily	27,074 passengers arrived at two sea ports
	Cargo ship		Crew		No information
	Yacht		Crew	Around1,700 to 1,800 per year	
	Fuel tanker		Crew		No information
	Military vessels		Military crew		No information
	Misc		Oil rigs, miscellaneous vessels		No information
Air	Private jet	Mainly USA, St Thomas	Passengers		About an average of 530 annually; peak season during Christmas/New Years, Easter and USA Thanksgiving Day
	Medevac	Mainly USA, Puerto Rico	Crew		No information
	Commercial	Caribbean region; various	Passengers	Daily	2,633 passengers arrived at the Clayton J. Lloyd International airport

With regards current exotic animal and plant ownership, Anguilla has no zoos or public aquaria, although St Maarten/Martin, 20 minutes away by ferry, has a butterfly farm featuring “hundreds of exotic butterflies” from all around the world, a potential source of non-native species. There is no botanic garden, although Anguilla Garden Centre stocks a wide range of imported exotic plant species, while Delonix Garden Centre grows primarily indigenous flora. However, the owner of Delonix is interested in establishing a collection of exotic animals and birds, including parrots, in the future. There is also an annual Anguilla Beautification Club (ABC) Flower and Garden Show. These indicate a certain level of interest in exotic ornamental plants species, but low current level of interest in exotic pets. Table 4 shows the status of exotic animal and plant presence and ownership.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Anguilla
Zoos		None
Botanic gardens		None
Public aquaria		None
Pet ownership:	Parrots	None
	Other cage birds	None
	Reptiles	Green iguana, red-footed tortoise, green anole
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs
	Other mammals	None
	Fresh water fish	None?
	Marine species	None

Existing non-native species

A total of 137 species met the parameters outlined in the methods section and were analysed, comprising 30 terrestrial invertebrate (16 insects, 13 arachnids and one mollusc), 8 terrestrial vertebrate, and 99 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Coleoptera 7
- Hemiptera 3
- Hymenoptera 3 (all ant species)
- Lepidoptera 3

The number of species considered to have been introduced via pathways of entry at the category level are given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above Note numbers add to more than 137 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport as a stowaway, mainly in shipping containers and vehicles followed by contamination of various commodities, mainly live plants. One species, a dung beetle, was deliberately released in nature for landscape improvement (to clear animal dung).

Vertebrates (one amphibian, one bird and six reptiles) were mainly considered to have escaped from confinement, having been introduced by the pet trade, although one species, the corn snake *Pantherophis guttatus* could also have been introduced as a stowaway in shipping containers, or transport contaminant of nursery or habitat material. A gecko, *Hemidactylus mabouia*, is considered most likely to have been introduced as a transport stowaway in shipping containers, and the flowerpot snake *Ramphotyphlops braminus* as transport contaminant in nursery or habitat material.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture (primarily as garden plants), followed by introduction for agriculture.

Table 5. Pathways of entry for 137 species at the category level.

	Invertebrates	Vertebrates	Plants	Overall
Release in nature	1	0	2	3
Escape from confinement	1	5	78	84
Transport – contaminant	13	2	20	35
Transport – stowaway	15	3	3	21

Table 6. Pathways of entry for 137 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control			
	Erosion control/ dune stabilization (windbreaks, etc)			2
	Landscape/flora/fauna “improvement” in the wild	1		
	Medical use			
	Release in nature for use (other than above, e.g., fur, transport, medical use)			
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	1		18
	Pet/aquarium/terrarium species (including live food for such species)		5	
	Forestry (including afforestation or reforestation)			2
	Horticulture			57
	Ornamental purpose other than horticulture			6
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	3	2	1
	Food contaminant (including of live food)	3		1
	Parasites on animals (including species transported by host and vector)	2		
	Contaminant on plants (except parasites, species transported by host/vector)	7		
	Parasites on plants (including species transported by host and vector)			
	Seed contaminant	1		17
	Timber trade	3		
	Transportation of habitat material (soil, vegetation)	1	1	9
TRANSPORT – STOWAWAY (4)	Container/bulk	15	3	
	Machinery/equipment			3
	People and their luggage/equipment (in particular tourism)	2		2
	Vehicles (car, train, …)	12		2

Source of non-native species

For Anguilla, there are three possible points of entry, two sea ports and one international airport, with direct access from within the Caribbean region. The possible source of non-native species is shown in Table 7 in terms of their geographic distribution, where data was available.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates species	Plants
Wider Caribbean	1	0	3
Wider Caribbean plus Americas	5	3	16
Americas (not wider Caribbean)	4	0	0
Asia/Oceania only	0	0	0
Other combination	0	0	4
Widespread	18	2	75

The majority of existing non-native species of all taxa have a widespread geographic distribution and are not restricted to the Caribbean region. Only a smaller number of invertebrate species have a current geographic distribution including only the wider Caribbean region plus mainland Americas and would therefore have arrived via more local pathways. Note that for plant species, geographic distribution is less informative as most introductions ae intentional.

Discussion

The majority of terrestrial invertebrates are considered most likely to have been introduced as transport stowaways. This is reflected in the main taxonomic groups represented in the database, all tending to stowaway; of the 30 terrestrial species 10 are spiders, seven are Coleoptera, and three are Hymenopteran tramp ants. Taxonomic groups associated with live plants are relatively few, as there are only three Hemipteran and three Lepidopteran species. The other terrestrial invertebrates consist of species of mite, a tick, and a mollusc.

Deliberate introduction is the main pathway of entry of plant species, primarily escapes from gardens or agricultural areas. Introduction as seed contaminant was also important.

The pet trade is the probable source of five of the eight vertebrate species, although this is not confirmed for the shiny cow bird; it is categorised in this report as having escaped from confinement but there is no evidence to support this (R. Connor, pers. comm.). The other species inferred for the pet pathway are all reptiles. Exotic pet ownership is not considered a particularly important pathway for Anguilla. The remaining four vertebrate species (three reptiles and one amphibian) are all considered most likely to have arrived as unintentional introductions. The African house gecko and flowerpot snake probably arrived as transport stowaway and contaminant, respectively, while the corn snake could have arrived via a number of different pathways, escaped pet, transport stowaway or contaminant.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated. This suggests that local trade is not as important as trade outside the wider

Caribbean region (including the rim countries) as the main ultimate pathway of introduction. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

Caveat

This analysis was done in 2017 prior to the impact of hurricanes Irma and Maria. Pathways may have changed post-hurricane.

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I am very grateful to Rhon Connor for his invaluable assistance in completing this report.

Ascension Island

Executive summary

- Points of entry to Ascension Island are relatively few, with direct access from St Helena, the UK, USA and the Falklands.
- Pathway analysis was done for 258 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants, then habitat material (eg compost, aggregate, etc.) followed by food (primarily fresh produce).
- Live and dead exotic vertebrates were intercepted in shipping containers.
- Exotic pet ownership is not considered an important pathway for Ascension Island.
- The main pathways of introduction for plants was escape from confinement, mainly following introduction for horticulture as garden plants
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Erosion control/ dune stabilization		*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)		*
	Forestry		*
	Horticulture		***
	Ornamental purpose		**
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*	*
	Food contaminant (including of live food)	***	
	Parasites on animals	*	
	Contaminant on plants	***	
	Seed contaminant		**
	Timber trade	*	
	Transportation of habitat material	***	***
TRANSPORT – STOWAWAY (4)	Container/bulk	***	*
	Hitchhikers on boat	*	
	Machinery/equipment	*	*
	Organic packing material	*	
	People and their luggage/equipment	*	*
	Vehicles (car, train, …)	*	

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for Ascension Island.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for Ascension Island by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for Ascension Island in 2014.

Taxon	Total species	Non-native species
Invertebrates	595	113
Vertebrates	140	16
Plants	324	103

The quality of baseline information in Ascension Island was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Basic

Sources of information

A biosecurity review for Ascension Island was carried out in 2016 by Biofume Pty Ltd of New Zealand (Biofume 2016) which included pathway analysis and checks of inbound cargo for invertebrates. Information from the Biofume report is included here.

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- Biofume (2016)

Visitor statistics are sourced from:

- Biofume (2016)

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Ashmole & Ashmole (2000)	Some information on introduction dates
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Ashmole & Ashmole (2000)	Some information on introduction dates

Results

Points of entry

There is one harbour, and a military airport operated by the US Airforce. US Airforce flights usually arrive once a fortnight, and approximately once a month RAF flights (the "airbridge") arrive from the Falklands/UK for MOD personnel and their contractors only. Up until April 2017, there were two scheduled military flights a week each way between the UK and the Falkland Islands. Monthly Airlink flights to and from St Helena are expected to start in November 2017. Note that the normal flight schedule can be disrupted by military or disaster and emergency relief activities.

Connectivity is summarised in Table 3 for 2015.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks (from Biofume 2016 and updated). GP = 20ft shipping container.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Air	US Airforce	Jacksonville, Florida, USA	Passengers and cargo	Fortnightly	Information not available
	RAF (UK) Airtanker	Marchwood (UK) and Falkland Islands (UKOT)	MOD Passengers	Monthly	Approx 42 pax/flight disembark
	Airlink	South Africa via St Helena	Passengers	Monthly	Max 76 pax per trip
Sea	RMS St Helena	Cape Town via St Helena	Passengers, military and commercial cargo	15 voyages	6 GPs 80 pax
	FIRS	Marchwood Naval Base, Southampton, UK	Military and commercial cargo	9 voyages	28 GPs 6 Chilled 3 Frozen
	USAF contracted cargo vessels	Port Canaveral (Florida, USA)	Military and contractor cargo	4 voyages	53 GPs
	Cruise ships	Varied	Passengers	7 voyages	164/vessel
	Yachts	Varied	Crew	47 yachts	Information not available

In 2015, a total of 4,368 people arrived via the RAF airbridge, together with 125.8 tonnes baggage, 120.3 tonnes airfreight and 50.8 tonnes food. It is assumed that an equivalent number of people and amount of cargo also arrived from the US. A total of 1,195 people disembarked from the RMS St Helena, mostly local residents returning to Ascension for work, plus some tourists. A further 1,151 passengers disembarked from cruise ships.

Of the 47 yachts which visited Ascension Island in 2015, 89% arrived after visiting St Helena, with 4% from Cape Town in South Africa.

Cargo arrives by both ship and plane. The RMS St Helena calls around 15 times a year from St Helena with passengers and cargo. From February 2018 a replacement ship will call with cargo only, on a monthly basis.

In 2015, a total of 322 20ft shipping containers were unloaded onto Ascension, 70 from St Helena and 252 from the UK, together with 120 consignments of break bulk and 137 vehicles. Further break bulk cargo arrives from the US.

With regards current exotic animal and plant ownership, there are no zoos, pet shops or botanic gardens or garden centres importing exotic animals or plants. Freshwater fish have historically & recently been brought in from St Helena.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Ascension Island
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	None
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	Dogs & cats (all cats are registered and neutered)
	Other mammals	None
	Fresh water fish	Gold fish, koi carp
	Marine species	None

<u>Existing non-native species</u>

A total of 258 species met the parameters outlined in the methods section and were analysed, comprising 97 terrestrial invertebrate (71 insects, 18 arachnids, five molluscs, two myriapods and one annelid worm) and 161 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hemiptera 27
- Coleoptera 11
- Hymenoptera 11
- Orthoptera 7
- Lepidoptera 5
- Diptera 6
- Thysanura 2
- Dermaptera 1

- Neuroptera 1

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 258 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants, then habitat material (eg compost, aggregate, etc.) followed by food (primarily fresh produce). The second commonest pathway of entry was as transport stowaway, mainly in shipping containers, which included most of the species of spider, scorpion, myriapod, cockroach, ant, cricket and Thysanura. Sixteen species could have arrived via two pathways at the category level, transport contaminant or stowaway, namely the earwig, general domestic pest species, ants, centipedes and some spiders. Insufficient information was found for one species to enable pathways to be inferred, the blackring ladybird *Oenopia cuneata*.

No non-native vertebrates have been introduced since 1980 (but see below, under interceptions).

For plants, the commonest pathway of entry of introduction was escape from confinement, mainly following introduction for horticulture as garden plants or, less commonly, introduction for agriculture. Less commonly, was introduction as transport contaminant, primarily of habitat material followed by seed. The habitat material implicated included aggregate, compost, hay and straw bedding. Five species could have arrived via two pathways at the category level, four as transport contaminant or transport stowaway and one as escape from confinement or transport contaminant.

Table 5. Pathways of entry for 258 species at the category level

	Invertebrates	**Plants**	**Overall**
Release in nature	0	1	1
Escape from confinement	0	127	127
Transport – contaminant	74	33	107
Transport – stowaway	36	5	41
Corridor	0	0	0
Unaided	1	0	1

Table 6. Pathways of entry for 258 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	1
	Hunting in the wild	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	9
	Pet/aquarium/terrarium species (including live food for such species)	0	0
	Forestry (including afforestation or reforestation)	0	2
	Horticulture	0	104
	Ornamental purpose other than horticulture	0	14
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	8	3
	Food contaminant (including of live food)	21	0
	Contaminant on animals	0	0
	Parasites on animals (including species transported by host and vector)	1	0
	Contaminant on plants (except parasites, species transported by host/vector)	36	0
	Seed contaminant	0	15
	Timber trade	2	0
	Transportation of habitat material (soil, vegetation)	25	25
TRANSPORT – STOWAWAY (4)	Container/bulk	34	1
	Hitchhikers on boat	1	0
	Hitchhikers on plane	0	0
	Machinery/equipment	2	3
	Organic packing material	2	0
	People and their luggage/equipment (in particular tourism)	2	2
	Vehicles (car, train, …)	9	0

Recent interceptions

During the biosecurity review in 2016, Biofume carried out a number of “snapshots”, namely inspection of imported cargo and shipping containers from the UK, US and St Helena. Results are summarised in Table 7.

Table 7. Live interceptions made during the biosecurity snap shots of sea cargo, summarised from Biofume (2016).

Origin	Goods / item checked	Invertebrates	Vertebrates	Other
St Helena	30 pieces of fresh produce	0	0	0
	3 x 20ft shipping containers	1 live millipede	0	0
	Pallets from the 20ft shipping containers	Webbing, live spiders	0	0
UK	13 x 20ft shipping container - exteriors	46% - spiders and snails	0	0
	13 x 20ft shipping container - interiors	71% - live contamination	0	20% - seeds
	8 x vehicles	50% - live spiders	0	25% - mud on the underside 12% - seeds
	50 x bulk bags aggregate	0	0	0
	10 x bulk bags shingle	0	0	2 recently uprooted grass seedlings in one bag
US Port Canaveral	4 x flat racks	Live ant nests	0	0
	28 x 20ft shipping containers - interiors	50% - live invertebrates (insects, spiders and snails)	1 *Hemidactylus* gecko	0

Live invertebrates included silverfish, a beetle, psocids, maggots, adult flies, cockroaches, and praying mantid egg rafts and case moth pupae with an unverified/emergence hatch rate. The viability and identity of the seeds was also not verified. Vehicles were particularly liable to be infested with spiders.

In addition to the live gecko found in one shipping container from the US, five dead frogs were also found in another.

Source of non-native species

For Ascension Island there are relatively few possible points of entry both by land and sea, with direct access only from St Helena, UK, USA and Falklands. The possible source of non-native species in terms of their geographic distribution is shown in Table 8.

Table 8. Geographic distribution of non-native species.

Possible source	Invertebrates	Plants
South Americas only	0	3
North Americas only	5	1
North and South Americas only	4	7
UK/Europe only	5	0
Africa only	4	2
Asia only	3	0
Other combination	26	29
Widespread	48	119

The geographic origin listed as “other combination” encompass a variety of distribution combinations, with a predominance of Europe plus North America and Europe plus Africa.

The majority of all existing non-native species of all taxa have a widespread geographic distribution, suggesting local trade is not important as the main ultimate pathway of introduction. Note that for plant species, geographic distribution is less informative as a large proportion of introductions are intentional.

Discussion

There is a small amount of agriculture in Ascension Island in the form of a hydroponics farm growing salad crops which started up in 2016; previously up until the early 2000s there had been extensive agriculture in the highlands in the form of Green Mountain Farm. Since 2016 biosecurity functions have been included in the terms of reference for the conservation officer, but these are necessarily limited.

The commonest inferred pathway for existing non-native species was mostly as a transport contaminant of live plants. No live plants were imported during the period of the Biofume snapshot surveys so it is not possible to compare this pathway. The second commonest inferred pathway was as transport stowaway of shipping containers. The importance of shipping containers was confirmed by Biofume and it can be seen from Table 7 that shipping containers (as well as vehicles) were found to contain large quantities of live spiders and snails, as well as live invertebrates of various taxa. A large proportion of existing non-native species are considered to have arrived as transport contaminant of food (primarily fresh produce and also cereals, and dried meat and fish produce). The fresh produce imported from South Africa checked by Biofume was found clean and uninfested. This may be unrepresentative of normal consignments, but is considered more likely to reflect the high standards demanded by Biosecurity St Helena over last few years, since 2014, as fresh produce comes from South Africa via St Helena and Ascension produce has to meet same import health standards as that for St Helena.

The newly established hydroponics farm is looking to introduce a range of biological control agents as part of their integrated pest management. The currently limited knowledge of native and endemic invertebrates makes it difficult to understand the risk this could have.

Habitat material, being sand, aggregate and composts, is inferred as an important pathway for both invertebrates and plants, and the only consignment of aggregate (shingle and sand)

inspected by Biofume was found to be good. Again, this may be unrepresentative of normal consignments or the importance of this pathway may be overestimated.

Currently, the introduction of vertebrates is tightly regulated but this only covers cats and dogs which must be neutered. Potentially, other animals could be brought in and escape, and there have been requests to bring in guinea pigs. Local legislation needs strengthening to remove this risk.

Three main pathways of introduction are implicated for plants: escape from confinement following introduction for horticulture, as transport contaminants of habitat material, and as transport contaminants of seeds. Habitat material consists of two main groups: aggregate, and organic material such as composts. Seed contaminant species are mainly small, annual species and grasses. Only introduction for horticulture can be regulated as an intentional introduction, and clearly transport contaminant is an important pathway.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

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I am very grateful to Dr Judith Brown for her invaluable assistance in completing this report.

British Antarctic Territory

Executive summary

- Points of entry to BAT are relatively few, with direct access only from the Falklands, Argentina, Chile, South Georgia and the UK.
- Pathway analysis was done for eight existing non-native species.
- For invertebrates, the commonest pathway of entry was as transport contaminant of food or transport stowaway of people or luggage.
- For vertebrates, the most likely pathway of entry is as transport stowaway on vessels.
- The pathways of introduction for the single species of plant recorded was transport stowaway, in machinery, people or luggage.
- Intra-continental transfer of non-native species is a big concern. 18 other nations operate within BAT, plus there are numerous tourist landing sites.
- UK/Europe is implicated as the geographic origin of most introduced species.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
TRANSPORT – CONTAMINANT (3)	Food contaminant	*		
TRANSPORT – STOWAWAY (4)	Container/bulk	*		
	Hitchhikers on boat		*	
	Machinery/equipment	*		*
	Organic packing material			
	People and their luggage/equipment)	*		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for British Antarctic Territory (BAT).

Baseline

The quality of baseline information in BAT was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity, visitor statistics and exotic animal and plant ownership were sourced from:

- https://www.gov.uk/world/organisations/british-antarctic-territory
- https://www.bas.ac.uk/polar-operations/sites-and-facilities/
- https://secure.antarctica.ac.uk/south/reports/itinerary.ship.php?numTravelTypeID=4
- https://iaato.org/tourism-statistics
- Data Collection and Reporting on Yachting Activity in Antarctica in 2016-17 (Anon. 2017)

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates and plants	Hughes et al (2015) Table A1	Comprehensive as of 2015
	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	Varnham (2006) Annex 4	Comprehensive from published data sources, up to date in 2005

Results

Points of entry

BAT has no permanent population, although there is a small transient population of researchers. Presence in the Territory is provided by the British Antarctic Survey (BAS), who operate three research stations: Halley VI Research Station, Rothera Research Station and Signy Research Station. Rothera is the largest British Antarctic facility, with up to 100 researchers in summer, and up to 70 people at Halley. Signy Research Station is only

occupied in summer and Halley will also close in winter from 2018. There are airstrips at Rothera and Halley Research Stations. A De Havilland Canada Dash-7 aircraft flies the "air bridge" between Rothera and the Falklands and Punta Arenas, Chile. The 1,900km journey can be completed in five hours with up to 16 passengers or 2,000kg of cargo on board. There are four Havilland Twin Otter aircraft based at Rothera and Halley Research Stations.

The supply vessels RRS *Ernest Shackleton* and RRS James Clark Ross support operations in BAT, as part of the British Antarctic Survey fleet, travelling between the UK, Falklands, South Georgia, Rothera and Halley over the summer season. The RRS *Ernest Shackleton* spends the southern winter in the northern hemisphere, in Europe and Canada. Cargo is loaded in Immingham, Grimsby or occasionally Portsmouth or Southampton. Some additional fresh foods etc. may be collected in South America, particularly at Punta Arenas.

The Royal Navy Ice Patrol Vessel HMS Protector operates around BAT.

The UK also supports the historic hut and post office run by the Antarctic heritage trust at Port Lockroy.

Tourists are landed from cruise ships at a number of landing sites, during the southern summer period. Over the 2016/2017 season, a total of 44,042 tourists visited the area on 50 cruise ships of which 36,907 passengers landed on the Antarctic Peninsula; 30% were from the USA, 14% from China and only 9% from the UK, with the remainder being made of various nationalities. The tourism industry operates out or Ushuaia or to a lesser degree Punta Arenas.

Connectivity is summarised in Table 3 for 2016/2017 season.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	**Point of origin**	**Description**	**Frequency per annum**	**Stats/trip**
Sea	RRS *Ernest Shackleton* and RRS James Clark Ross	UK, Falklands, SGSSI, Chile	Researchers, cargo	2-4 trips	Ca 25 crew plus science/support staff in transit
	HMS Protector	UK, Falklands, SGSSI, South America	Crew	Operates within region	
	Cruise ships	Falklands, South America, SGSSI	Passengers	50	44,042 pax
	Yachts	Falklands, South America, SGSSI	Crew	32	
Air	Dash-7	Falklands, Chile	Passengers, cargo	Routine flights within region in season	Up to 16 pax per trip
	Havilland Twin Otters	Falklands, Chile	Passengers, cargo	Routine flights within region in season	

It is important to note that other nations access the Antarctic Peninsula from, for example Argentina, Brazil, Uruguay, Poland, Spain, the US, etc. There are also numerous other research stations and facilities operated by 18 other nations operating within BAT which, in

many ways, present the greater risk as biosecurity standards may not be as high as they are for the BAS.

With regards current exotic animal and plant ownership, there are no zoos, pet shops or botanic gardens or garden centres importing exotic animals or plants. Non-native species are prohibited (unless a permit has been issue) under Annex II of the Protocol on Environmental Protection to the Antarctic Treaty

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence in BAT
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	None
	Other	None
	Amphibians	None
	Domestic cats, dogs, etc.	None
	Other mammals	None
	Fresh water fish	None
	Marine species	None

Existing non-native species

A total of nine species met the parameters outlined in the methods section and were analysed, comprising eight terrestrial invertebrate (five insects and two arachnids, both mites), one vertebrate (a rat) and one terrestrial plant species.

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note that numbers add to more than nine as one species has two possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant of food or stowaway, primarily of cargo (including vehicles and supplies for station construction), although via soil on boots is also a possibility.

Rats *Rattus norvegicus* have been introduced to King George Island, South Shetland Islands, but did not survive the climatic conditions given the lack of shelter. Rats are assumed to have arrived as transport stowaways aboard a vessel.

A single plant species the grass *Poa annua* has been introduced to a number of locations since 1980. The method of importation is unknown but is likely to be as a transport stowaway associated with machinery or cargo, although peoples' clothing, footwear and luggage will also be important for transfer between locations within the region.

Table 5. Pathways of entry for nine species at the category level

	Invertebrates	Vertebrates	Plants	Overall
Release in nature	0	0	0	0
Escape from confinement	0	0	0	0
Transport – contaminant	7	0	0	7
Transport – stowaway	7	1	1	9
Corridor	0	0	0	0
Unaided	0	0	0	0

Table 6. Pathways of entry for nine species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	0
	Hunting in the wild	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	0
	Pet/aquarium/terrarium species (including live food for such species)	0	0	0
	Forestry (including afforestation or reforestation)	0	0	0
	Horticulture	0	0	0
	Ornamental purpose other than horticulture	0	0	0
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	0	0	0
	Food contaminant	7	0	0
	Contaminant on animals	0	0	0
	Parasites on animals (including species transported by host and vector)	0	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	0	0	0
	Seed contaminant	0	0	0
	Timber trade	0	0	0
	Transportation of habitat material (soil, vegetation)	0	0	0
TRANSPORT – STOWAWAY (4)	Container/bulk	7	0	0
	Hitchhikers on boat	0	1	0
	Hitchhikers on plane	0	0	0
	Machinery/equipment	7	0	1
	Organic packing material	0	0	0
	People and their luggage/equipment (in particular tourism)	7	0	1
	Vehicles (car, train, …)	0	0	0

Source of non-native species

For BAT there are a large number of possible points of entry both by land and sea, from a range of countries. The possible source of non-native species in terms of their geographic distribution is shown in Table 7.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
UK/Europe only	3	0	0
Other combination	4	0	0
Widespread	0	1	1

The "other combination" was UK/Europe and North America in three cases and North America only in one case. The UK/Europe is strongly implicated as the source of most non-native species.

Discussion

There are permanent settlements but not permanent populations in BAT, with some research stations having been operating continuously for 60 years or more. There is no agriculture and consequently all inferred pathways are unintentional, either as transport stowaways of general cargo, clothing, footwear and luggage, or transport contaminants of food. Machinery is a known risk category, with four construction vehicles imported as recently as 2005 from the Falkland Islands and South Georgia and found to be heavily contaminated with soil and associated plant seeds and microorganisms (Hughes et al, 2010). Once introduced there is a likelihood of further transfer within Antarctica on footwear and luggage.

Both researchers and tourists are implicated in the introductions, although researchers are a more likely pathway as they bring more and a wider range of personal goods to the region, despite being fewer in numbers than tourists; tourists may only spend a few hours, in total, on the ground in Antarctica while researchers may spend many weeks or months.

The majority of existing non-native invertebrates are Collembola and mites, all of which are small, readily transported inadvertently and associated with mud or detritus. The single species of true insect, the winter crane fly *Trichocera (Saltrichocera) maculipennis* (Diptera) is also associated with detritus. The single plant species is a grass, *Poa annua*, which has small spiky seeds highly likely to be transported accidentally in mud or detritus, or attached to clothing and footwear. The invertebrates are not considered likely to have been introduced in soil as part of the transplantation experiment of *Nothofagus* trees in the 1950s which resulted in accidental introduction of the grass *Poa pratensis* as Pertierra et al did not find non-native invertebrates particularly associated with soil under *P. pratensis* (Pertierra et al 2017).

An identified weakness during the gap analysis carried out in early 2017 is the risk of intra-continental transfer of non-native species from the other 18 nations operating within the BAT area, as standards of compliance are unclear. In addition, transfer of species between tourist landing sites via footwear, and between research stations via footwear and general luggage, is also of concern.

Most existing non-native species have a northern European or widespread distribution with European origin, a feature noted by Frenot et al (2005) of Antarctic invasions in general. Species enter the transport chain either in the UK or at port areas in South America or the Falklands where cosmopolitan non-native species are common.

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Bermuda

Executive summary

- Points of entry to Bermuda are several, with direct access from a number of other countries outside the Caribbean region both by air and sea.
- Pathway analysis was done for 519 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For vertebrates, the commonest pathways of entry were escape from confinement and transport contaminant.
- Exotic pet ownership is potentially considered an important pathway for Bermuda.
- For plants, escape from confinement was the commonest pathway of entry.
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*		
	Erosion control/ dune stabilization			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			**
	Botanic garden or zoo		*	
	Pet/aquarium/terrarium species		*	
	Forestry			*
	Horticulture	*		***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	***		*
	Food contaminant (including of live food)	***		
	Contaminant on animals	*		
	Parasites on animals	**		
	Contaminant on plants	***	*	
	Seed contaminant	*		**
	Timber trade	*		
	Transportation of habitat material	***		*
TRANSPORT – STOWAWAY (4)	Container/bulk	***	*	
	Hitchhikers on boat	***		
	Hitchhikers on plane	*		*
	Machinery/equipment	*		
	Organic packing material	*		
	People and their luggage/equipment	*	*	
	Vehicles (car, trucks …)	*		

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for Bermuda.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for Bermuda by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for Bermuda in 2014.

Taxon	Total species	Non-native species
Invertebrates	5,708	467
Vertebrates	1,281	32
Plants	2,348	402

The quality of baseline information in Bermuda was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/

Visitor statistics are sourced from:

- http://www.gotobermuda.co.uk/sites/default/master/files/2016_visitor_arrivals_report0320.pdf

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Sterrer et al (2003): Bermuda – an island biodiversity transported	Comprehensive.
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	An Illustrated guide to Bermuda's indigenous and invasive plants (2016)	Up-to-date for the most common non-native species

Records of plants were checked in Flora of Bermuda (1918) and the Bermuda Garden Club book from 1971 to remove all species recorded before 1980. The same exercise was done for the Coccinellidae, Psocoptera, Molluscs, and planarians and nemertines of Bermuda using the checklists of Gordon & Hilburn (1990), Mockford (1989), Bieler & Slapcinsky (2000) and Jones & Sterrer (2005).

Results

Points of entry

There is one international airport, with daily direct flights to US, Canada and the UK. There are no direct flights within the region.

Ferry services run within Bermuda, between 12 ferry docks. Since 2013 a ferry has been chartered from a private company to assist with transporting Bermuda based passengers from one end of the Island to the other during peak tourist season. It returns to the USA (Rhode Island) for the off season. For the 2017 summer season a second ferry was also brought in for this service by Norwegian Cruiseline. There are no regular international ferry services.

Cruise ships depart cruise ports for Bermuda from the Azores, Canada (Nova Scotia), Guatemala, Panama canal, and the USA (Florida, Maryland, Massachusetts, New York, Pennsylvania, Virginia), and within the region from the Bahamas, Cuba, Puerto Rico and USVI. Cruise ships call at three locations, Hamilton, St George's Harbour and the Royal Naval Dockyard at the West End. Yachts have only one port of entry, St George's Harbour, but once they have cleared Immigration and Customs in St. Georges they can take up anchorage anywhere.

Cargo arrives by both ship and plane. Within the region, cargo is mainly flown in from the USA but also arrives on the British Airways flight from the UK. There are at least 6 different companies on Bermuda that are directly involved with the air cargo business. One local company offers air consolidation service from USA, Canada, UK, Europe and the Far East (the latter goes through Dubai before being expedited to Bermuda).

Cargo arrives by ship from the USA, mainly from New Jersey and Jacksonville, Florida, with two regularly scheduled weekly callers in addition to car-carriers and special cargo ships, for example unloading gravel and building supplies for the new airport. The MV Oleander has a weekly service to Bermuda from Port Elizabeth New Jersey and the MV Bermuda Islander

from Salem, New Jersey and New York. Since 1979 the company operating from New Jersey has delivered ca. half million containers and countless vehicles, boats, and heavy equipment to Bermuda.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	**Point of origin**	**Description**	**Frequency per annum**	**Stats/trip**
Sea	Cruise ship	Various	Passengers and crew	139	397,904
	Ferry	USA: Rhode Island	Crew	Once	N/A
	Yacht	Various, including within the Caribbean region	Crew	811	4,070
	Cargo ship	USA: New Jersey, Florida (Jacksonville)	Crew	NJ freight weekly FL freight every 10 days	Cargo
		Japan, via numerous ports	Crew	monthly	New and used vehicles
	Fuel tanker		Crew		Several times a year
	Military vessels		Crew	Yearly missions	USA coastguard US navy frigate UK navy frigate
	Foreign fishing vessels and sport fishing vessels	USA: usually Florida	Crew	annual visits	For the Billfish Blast and other tournaments – they remain in Bermuda all summer.
	Sail training ships and tall ships	Europe and north America	Crew	about 10 visits per year	
	Foreign research vessels	Europe or USA	Crew	about 2 visits per year	
Air	Private jet	Various	Passengers and crew	Approx. 10 per week	520 a year
	Commercial	USA, Canada, UK, Europe	Passengers		244,491
	Cargo	USA, Canada, UK, Europe and the Far East	Crew, cargo	Daily	
	Medevac				No information

In 2016, a total of 139 cruise ships carrying a total of 397,904 passengers visited Bermuda, and 4,070 passengers arrived by yacht. In the same period 244,491 visitors arrived by air. A total of 90% of cruise passengers had US or Canada as country of origin, and for yacht

passengers this was 57%, with 33% from UK or Europe. Several yacht regattas are held each year, originating from the USA.

With regards current exotic animal and plant ownership, Bermuda has one exotic animal collection, the Bermuda Aquarium, Museum & Zoo, with a collection of native and non-native wildlife from oceanic islands around the world. The national botanical gardens consists of woodland, greenhouses, agricultural buildings and horticultural collections, and is noted to be chiefly of interest for its trees, orchard, and collection of orchids. The arboretum park has a collection of trees and shrubs from around the world.

There are three plant nurseries which import ornamental plants, and at least three pet shops selling a range of exotic mammal, reptile, bird and fish species, as well as fresh water snails and live aquatic plants. Table 4 shows the status of exotic animal and plant presence and ownership.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Bermuda
Zoos	Includes animals and animals imported for feeding the collection	Bermuda Aquarium, Museum & Zoo
Botanic gardens		Bermuda Botanical Gardens, Arboretum
Public aquaria	Native marine species	Bermuda Aquarium, Museum & Zoo
Pet ownership:	Parrots and cage birds	Parakeets, cockatoos, macaws, cockatiels, finches, other parrots (African greys in particular)
	Reptiles	Red-eared sliders, tortoises (various species)
	Amphibians	Newts
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits, guinea pigs, hamsters, gerbils, chinchillas
	Other mammals	Hedgehogs (for a limited time, now prohibited)
	Fresh water fish	Many species, including goldfish, koi, gourami, cichlids, danios, angel fish, guppies, tetras, neons, catfish, Plecos, algae eaters, feeder fish, etc
	Marine species	Only native species allowed (collecting requires a permit)

<u>Existing non-native species</u>

A total of 519 species met the parameters outlined in the methods section and were analysed, comprising 383 terrestrial invertebrate (311 insects, 44 arachnids, 15 Oligochaetes, six myriapods, four planarians/nemerteans and three molluscs), 10 terrestrial vertebrate (seven reptiles and three birds), and 126 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Diptera 107
- Hemiptera 42
- Lepidoptera 41
- Thysanoptera 35

- Coleoptera 30
- Hymenoptera 17
- Orthoptera 17
- Psocoptera 12
- Collembola 4
- Isoptera 2
- Dermaptera 2
- Embioptera 1
- Neuroptera 1

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 519 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants, and transport of habitat material (related to the presence of soil and aggregate). Contaminated food (mostly fresh produce) and nursery material (soil) were also important pathways. The transport stowaway pathway was the next commonest, mainly via shipping containers followed by hitchhikers on boats. Multiple introductions are recorded for the mosquito *Aedes aegypti*, which was eradicated in the early 1960s and then recorded in 1982 and 1998. It is therefore included in the analysis due to the post-1980 introductions despite having been recorded before then.

Four species were deliberate introductions as biological control agents: *Cactoblastis cactorum* (Lepidoptera), *Ageniaspis citricola* (parasitic wasp), *Exochomus californicus* (ladybird) and *Hemisarcoptes malus* (predatory mite). Two species are considered to be deliberate introductions which have escaped from confinement, having been introduced for vermiculture in the horticultural trade: *Eisenia foetida* and *Eudrilus eugeniae*, both oligochaetes.

Data was particularly hard to find for molluscs and Oligochaete worms in the time available for this analysis. Of the 15 species of Oligochaete worm, no information was gathered for four species and data on current geographic distribution lacking for a further four species.

A total of 23 invertebrate species could have arrived via two pathways at the category level, transport contaminant or stowaway, including a number of ant, centipede, spider, cockroach and general cosmopolitan household pest species.

For vertebrate species, the commonest pathway of entry was transport contaminant or stowaway followed by escape from confinement. Two species of house gecko, *Hemidactylus turcicus* and *H. mabouia*, and two species of anolis lizard, *Anolis sagrei* and *A. carolinensis,* probably arrived as transport stowaways; all except the latter subsequently became established on Bermuda. The red-eared slider *Trachemys scripta elegans* was originally introduced through the pet trade, but escape from confinement (and intentional release of unwanted pets) led to the establishment of feral populations in fresh water wetlands across Bermuda.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture as garden plants, or, less commonly, introduction for agriculture or for amenity planting. The second commonest pathway of entry was via transport contaminant, primarily of seed, followed by habitat material; these species are mainly grasses and small annual weeds. One plant species, the beach naupaka *Scaevola taccada* most probably arrived via marine currents from the Caribbean and / or US mainland.

One species, *Ageratina adenophora,* crofton weed, could have arrived via two pathways at the category level, as escapes from confinement or as transport contaminant.

Ports of entry have been mapped by the Department of Environment and Natural Resources, Bermuda, see Figure 1.

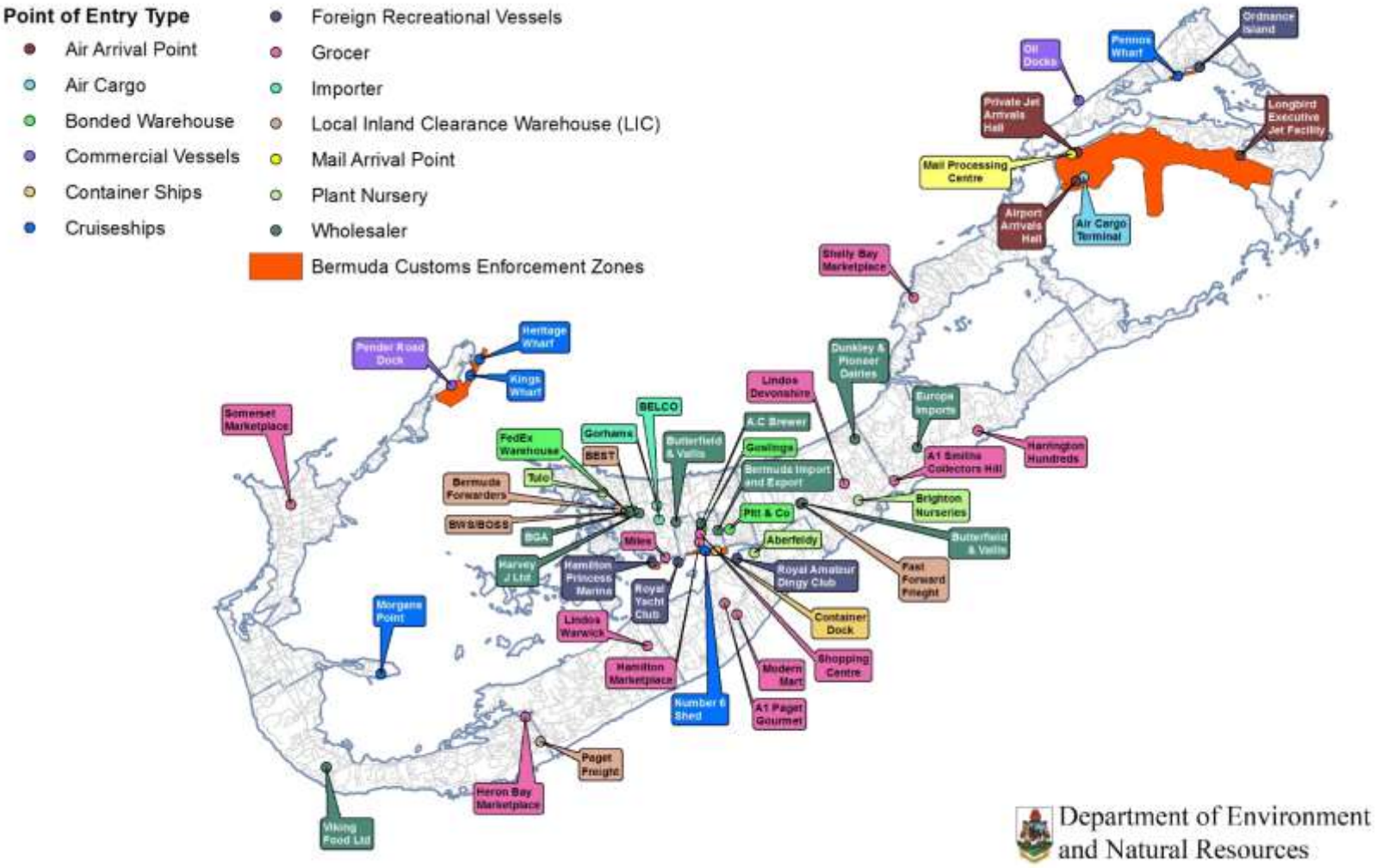
Table 5. Pathways of entry for 519 species at the category level

	Invertebrates	**Vertebrates**	**Plants**	**Overall**
Release in nature	4	0	1	5
Escape from confinement	2	7	101	110
Transport – contaminant	323	3	24	348
Transport – stowaway	74	2	0	78
Corridor	0	0	1	2
Unaided	0	0	0	2

Table 6. Pathways of entry for 519 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	4	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	1
	Hunting in the wild	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	16
	Botanic garden or zoo	0	1	0
	Pet/aquarium/terrarium species (including live food for such species)	0	6	0
	Forestry (including afforestation or reforestation)	0	0	1
	Horticulture	2	0	76
	Ornamental purpose other than horticulture	0	0	9
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	25	0	3
	Food contaminant (including of live food)	48	0	0
	Contaminant on animals	4	0	0
	Parasites on animals (including species transported by host and vector)	17	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	182	3	0
	Seed contaminant	1	0	18
	Timber trade	5	0	0
	Transportation of habitat material (soil, vegetation)	108	0	10
TRANSPORT – STOWAWAY (4)	Container/bulk	57	1	0
	Hitchhikers on boat	22	0	0
	Hitchhikers on plane	5	0	1
	Machinery/equipment	9	0	0
	Organic packing material	4	0	0
	People and their luggage/equipment (in particular tourism)	10	1	0
	Vehicles (car, train, …)	4	0	0

Figure 1. Map of the human-mediated points of entry in Bermuda, by importer.



Recent interceptions

Some data on interceptions is given below, in Tables 7 (intentional introductions) and 8 (unintentional introductions) brought in on two pathways, the pet trade and transport stowaways; note that this is by no means exhaustive but represents readily accessible records.

Table 7. Interceptions of intentional introductions brought in for the pet trade.

Date	Species	Detail
Jan. 1995	Royal ball python	Confiscated at airport. Snake was in a cloth bag in private luggage.
2004	Tarantula spider	Confiscated by customs agent at FedEx. Spider was found in a private parcel, apparently being sent to a local resident as a pet.
Aug. 2016	2 box tortoises (alive) 2 wood turtles (dead)	Confiscated at airport, shipment was in transit to Hong Kong. Customs x-rayed the box at the mail sorting facility.
April 2017	Royal ball python	Confiscated at airport. Snake was in private luggage.

Table 8. Interceptions of unintentional introductions brought in as transport stowaways.

Date	Species	Detail
1994	Snake (not identified)	Found in a container being used in the demolition of a hotel
Feb. 2000	Green iguana	Found on cargo docks in Hamilton where cargo ship unloaded
Oct. 2004	Black racer snake	Found in hull of a cargo boat. *Company* provides a direct ocean freight service linking Bermuda with the port of Fernandina Beach (Jacksonville) Florida.
Nov 2004	Snake (not identified)	Found in Bermuda Forwarder's yard in Hamilton City (this business is involved with international cargo shipping services, trucking, container haulage, import, export, etc.)
Ca. 2004	Snake (not identified)	Found in a fumigated container on retailer premises in Hamilton City
Nov. 2011	Brown anole lizard (juvenile)	Found by a farmer in a bale of sphagnum imported from Florida
March 2016	Green anole lizard	Found on cargo docks in Hamilton where cargo ship unloaded
May 2014	Frog (not identified)	Found on a commercial property in a container that had been sent from Thailand (via Baltimore, USA).
Sept. 2014	Orb web spider (not identified)	Found on a commercial property in container carrying animal fodder.
Oct. 2014	Large tree frog (not identified)	Found in a commercial boat yard on outskirts of Hamilton City, in a covered boat that had been shipped from Florida.

Source of non-native species

For Bermuda, there are several possible points of entry both by land and sea, with direct access from the UK and USA as well as private yachts within the Caribbean region. The possible source of non-native species in terms of their geographic distribution is shown in Table 9.

Table 9. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	14	0	3
Wider Caribbean plus Americas	39	1	4
Americas (not wider Caribbean)	96	4	10
Europe only	4	1	2
Africa only	0	0	2
Asia/Oceania only	1	0	4
Other combination	18	2	18
Widespread	179	1	84

The majority of all existing non-native species of all taxa have a widespread geographic distribution. A relatively small number of species are known from the wider Caribbean region plus mainland Americas, suggesting local trade is not as important as trade outside the wider Caribbean region (including the rim countries) as the main ultimate pathway of introduction. Note that for bird and plant species, geographic distribution is less informative as most introductions ae intentional.

Discussion

The majority of terrestrial invertebrates are considered most likely to have been introduced as transport contaminants, mainly of live plants and associated soil (nursery material and habitat material), or as food contaminants, namely of fresh produce or dried stored produce. The database includes a big group of Hemiptera, Diptera, Lepidoptera, Psocoptera, Thysanoptera, molluscs and Oligochaete worm species associated with plants, soil or habitat material (e.g. pea gravel, potting soil, peat moss, revetment stone, etc.).

There are relatively few transport stowaways, typically species in the taxonomic groups Dermaptera, Coleopteran, Orthoptera and Hymenoptera, together with Arachnids and Myriapods (centipedes). Currently, animal fodder is imported, a potential habitat material and checked when large amounts arrive. Soil can only be imported once it has been treated. One point of concern are untreated pallets and dunnage that are regularly brought in as treatment is not required for Bermuda. Also of concern are the large amounts of untreated aggregate being imported from Canada for construction projects. Jones & Sterrer (2005) consider the influx of planarian and nemertean worms to be due to surge in imports of containers loads of lumber, furniture, tiles and sand from around the world since the 1990s.

Four species of invertebrate biological control agents have been introduced since 1980. Biological control in Bermuda has a long history, with the introduction of “thousands of individuals” of at least 44 species of Coccinellidae between 1948 and 1951 to control the cedar scale, from which nine species established (Gordon & Hilburn 1990).

It proved particularly difficult to infer pathways of entry for Oligochaete worms. There is a lack of information in general for this less well studied taxon, and very little refers to life history or pathways of introduction or spread, with a few exceptions: at least two species are traded internationally for vermiculture. The Global Invasive Species Database notes that earthworms were probably originally introduced to the US as adults or cocoons in dry ship ballast, and that one of the major current pathways for earthworm introductions is believed to from release by anglers discarding unwanted live bait (http://www.iucngisd.org/gisd/species.php?sc=1697). Soil associated with the live plant trade as well as top soil, sand and similar substrate imported for golf courses and general landscaping is also potentially a source of earthworms.

Deliberate introduction is the main pathway of entry of plant species, mainly for horticulture, which then escape from gardens or agricultural areas. Introduction as a contaminant of seed or nursery material was also important, mainly small annual weeds and grasses.

Exotic pet ownership is popular and this is potentially considered an important pathway for Bermuda. The pet trade is considered the source of the exotic birds as well as the aquatic fishes and many of the snakes (although it is illegal to import the latter) encountered in Bermuda's environment. Of the interceptions, four were of intentional introductions of reptiles and a tarantula for the pet trade. However, over the same broad period of time, nine unintentional interceptions were made of reptiles and amphibians as transport stowaways, indicating the potential importance of this pathway for non-native vertebrate introductions.

An emerging issue for Bermuda is that of landscapers taking soil, plants and other materials around the island and acting as vectors for dissemination of introduced species.

Internal biosecurity is of concern, and specifically with regards to Nonsuch Island which has been restored and where a high level quarantine is implemented.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism. Bermuda has strong direct connections to the US and Europe and not to the Caribbean countries, explaining the relative unimportance of the Caribbean region as a source of non-native species.

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British Indian Ocean Territory

Executive summary

- Points of entry to BIOT are restricted to non-commercial flights, with direct access from Singapore, Bahrain and other countries both by air and sea.
- Pathway analysis was done for 212 existing non-native species that were first recorded since 1980.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For vertebrates, the commonest pathways of entry were escape from confinement and transport stowaway.
- For plants, escape from confinement was the commonest pathway of entry.
- It is believed these introductions reflect pre-1971 pathways of entry, with existing species only entering the database post-1980.
- Exotic pet ownership is no longer considered an important pathway for BIOT.
- Live plants for horticulture and agriculture are no longer imported.
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*	*	
	Erosion control/ dune stabilization			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			***
	Pet/aquarium/terrarium species		*	
	Horticulture			***
	Ornamental purpose			**
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material			*
	Food contaminant (including of live food)	*		
	Contaminant on animals			*
	Contaminant on plants	*		
	Seed contaminant			***
	Timber trade	*		
	Transportation of habitat material			***
TRANSPORT – STOWAWAY (4)	Container/bulk	*	*	*
	Hitchhikers on boat		*	
	Hitchhikers on plane			*
	Machinery/equipment			*
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)			*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the separate document “Pathway analysis – methods”.

This report presents the results of the pathway analysis for the British Indian Ocean Territory (BIOT).

Baseline

An overview of numbers of species recorded for BIOT by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for BIOT in 2014.

Taxon	Total species	Non-native species
Invertebrates	1,302	6
Vertebrates	1,002	21
Plants	534	235

The quality of baseline information in BIOT was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from participants at the BIOT Conservation Management Plan workshop, 5 – 6 March 2018.

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date

Results

Points of entry

There is a military airport and harbour on the main island, Diego Garcia. There are no commercial flights and permits are only issued to yachts in safe passage through the archipelago. Between 2007 and 2017 an annual average of 50 yachts were issued licenses to visit BIOT, varying from 16 to 105.

Cargo arrives by both ship and plane. Within the region, cargo is flown in from Bahrain and Singapore and by cargo ship from Singapore and Guam. Military passenger planes arrive from Bahrain and Singapore, each approximately two to three times a week.

Other military vessels (including submarines) can come from anywhere and berth in Diego Garcia, while other military flights can come from Okinawa (Japan), Australia and other points of origin. These are generally on short stop-overs.

A patrol vessel travels between Diego Garcia and the outer islands, which may take shelter in the lagoon of outer islands. Smaller rib boats are used for landing and passengers swim ashore. Military ships also move within the archipelago, berthing alongside the wharf in Diego Garcia and anchored off shore in the outer islands.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship		Passengers and crew		None
	Ferry	None	N/A	N/A	N/A
	Yacht	Various	Crew		Average of 50 a year
	Cargo ship, MV Corsica	Singapore	Crew	Once a month	12 visits a year
	Fuel tanker		Crew		No information
	Military vessels	USA, UK, Australia?	Crew		No information
	Misc, eg oil rigs				None
Air	Private jet		Passengers and crew		None
	Passenger	Bahrain, Singapore	Passengers		None
	Military	USA, UK, Australia, Singapore, Bahrain, Guam	Passengers and crew		No information
	Cargo	Singapore, Bahrain, Japan (Okinawa)	Crew, cargo		No information
	Medevac				No information

With regards current exotic animal and plant ownership, since 1971 there is no permanent population in BIOT and consequently no zoos, pet shops or botanic gardens. One plant nursery is growing native hardwoods for local use within Diego Garcia. Currently inhabitants

are UK and US military personnel and civilian contract employees, all living on Diego Garcia. Importation of live animals as pets and plants is not permitted; note that police dogs are used and travel in and out of BIOT.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on BIOT
Zoos		None
Botanic gardens		None; 1 nursery growing native hardwoods
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	None
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	None
	Other mammals	None
	Fresh water fish	None
	Marine species	None

Existing non-native species

A total of 212 species met the parameters outlined in the methods section and were analysed, comprising 12 terrestrial invertebrate (all insects), seven terrestrial vertebrate (six reptiles and one bird), and 192 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hemiptera 6
- Coleoptera 4
- Hymenoptera 2

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 212 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants and food (primarily fresh produce). Intentional introduction as biological control agent was the next commonest pathway of entry, for the control of either the rhinoceros beetle or banana weevil. One species could have arrived via two pathways at the category level, transport contaminant or stowaway, namely the yellow crazy ant.

Of the eight introduced vertebrate species (one amphibian, two birds and five reptiles), the commonest pathways of entry were escape from confinement and transport stowaway. The oriental garden lizard and two species of terrapin probably arrived in the pet trade, while the house crow and two species of house gecko probably arrived as transport stowaways, on ships for the house crow and in shipping containers for the geckos. The cane toad was deliberately introduced for biological control of insect pests.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture as garden plants, or, less commonly, introduction for agriculture. The second commonest pathway of entry was via transport contaminant, primarily of seed,

followed by habitat material; these species are mainly grasses and small annual weeds, together with *Cyperus* species. One plant species, the beach bean *Canavalia* sp. most probably arrived into the territory unaided, via marine currents.

Thirteen species could have arrived via two pathways at the category level, eight species as transport contaminant or stowaway, four species as escapes from confinement or as transport contaminant, and one species as release in nature or escape from confinement.

Table 5. Pathways of entry for 212 species at the category level

	Invertebrates	**Vertebrates**	**Plants**	**Overall**
Release in nature	4	1	1	6
Escape from confinement	0	3	130	133
Transport – contaminant	8	0	63	71
Transport – stowaway	1	3	9	13
Corridor	0	0	1	1
Unaided	0	0	0	0

Table 6. Pathways of entry for 212 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	4	1	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	1
	Hunting in the wild	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	25
	Pet/aquarium/terrarium species (including live food for such species)	0	3	0
	Forestry (including afforestation or reforestation)	0	0	0
	Horticulture	0	0	88
	Ornamental purpose other than horticulture	0	0	17
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	0	0	9
	Food contaminant (including of live food)	5	0	0
	Contaminant on animals	0	0	1
	Parasites on animals (including species transported by host and vector)	0	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	8	0	0
	Seed contaminant	0	0	48
	Timber trade	1	0	0
	Transportation of habitat material (soil, vegetation)	0	0	33
TRANSPORT – STOWAWAY (4)	Container/bulk	1	2	2
	Hitchhikers on boat	0	1	0
	Hitchhikers on plane	0	0	1
	Machinery/equipment	0	0	8
	Organic packing material	0	0	0
	People and their luggage/equipment (in particular tourism)	1	0	2
	Vehicles (car, train, …)	0	0	4

Recent interceptions

A list has been kept since1995 of hitchhiker species intercepted in Diego Garcia, with country of origin where known, see Table 7. Recently a live python was intercepted in a cargo of bananas from Singapore.

Table 7. Hitchhiker species intercepted in Diego Garcia.

Year	Species	Country of origin	Carrier
1995	Saw Scaled Viper, alive	Oman	Air cargo
	Sun Spider (Solfugidae)	Oman	Air cargo
2000	Agama Lizard	Unknown	Unknown
	Black Widow Spider	Hawaii	Air
2003	Common House Snake, dead	Unknown	Household Goods
	Reticulated Python, alive	Singapore	Air cargo
	Roof Rat (White Bellied), alive	Kadena Air Base	Air cargo
2006	Black Widow Spider	Unknown	Air cargo
	Black/Brown Widows Spiders	N/A	Sea vessel
2007	Black/Brown Widows Spiders	Sri Lanka	Fishing vessel
2008	Black/Brown Widows Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Singapore	Sea Vessel
	Sparrow	Middle East	Air cargo
	Black/Brown Widows Spiders	Unknown	Sea Vessel
2009	Black/Brown Widows Spiders	Unknown	Sea Vessel
	Giant African Snail, alive	Singapore	Sea cargo
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Black/Brown Widows Spiders	Unknown	Sea Vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
2010	Fungus (Gill Split Mushrooms)	Singapore	Sea cargo
	Black/Brown Widows Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Giant Centipede	Sri Lanka	Fishing vessel
2011	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Bed Bugs	Unknown	Personal luggage
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Unknown	Sea Vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
2012	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Unknown	Sea Vessel
	Brown Widow Spiders	Unknown	
	Brown Widow Spiders	Sri Lanka	Fishing vessel
2013	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
2014	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Unknown	Sea cargo

	Brown Widow Spiders	Sri Lanka	Fishing vessel
2015	Common House Spider	Singapore	Sea cargo
	Common House Spider	Singapore	Sea cargo
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spiders/American cockroaches	Sri Lanka	Fishing vessel
2016	Brown Widow Spiders	Sri Lanka	Fishing vessel
	Brown Widow Spider	Sri Lanka	Fishing vessel
	Brown Widow Spider	India	Sea Vessel
2017	Garden snail *Cornu aspersum*	Possibly Singapore	Sea cargo
	Brown & Black Widow Spider	Sri Lanka	Fishing vessel

Source of non-native species

For BIOT there are very few possible points of entry both by land and sea, with direct access only from Bahrain and Singapore. The possible source of non-native species in terms of their geographic distribution is shown in Table 8.

Table 8. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	0	0	0
Wider Caribbean plus Americas	0	0	5
Americas (not wider Caribbean)	1	0	3
Europe only	0	0	0
Africa only	0	1	8
Asia/Oceania only	0	2	9
Indian Ocean only	0	0	1
Other combination	2	0	16
Widespread	7	3	149

The majority of all existing non-native species of all taxa have a widespread geographic distribution, suggesting local trade is not important as the main ultimate pathway of introduction.

Note that for plant species, geographic distribution is less informative as most introductions are intentional.

Discussion

There are now no economic, industrial or agricultural activities on the islands apart from construction projects and other support services as part of the US defence facility on Diego Garcia. This limits the number of possible pathways for the introduction of non-native species as imports such as live plants and pets have not been allowed since 1971, although there is suspected to be some illegal importation of plant seeds. The apparent contradiction with the inferred pathways of introduction for existing non-native species first recorded since 1980 (implicating intentional introductions of live plants for horticulture or agriculture and

introduction as pets) are probably due to introductions made pre-1971 but which only got recorded post-1980. This may be due either to first detection in the field post-1980 or first entry in a database post-1980.

Singapore is the main origin of flights and cargo vessels arriving in BIOT. However, Singapore is a transport hub and so is probably not the point of origin of at least some if not all of the goods being transhipped to BIOT. Detailed analysis of the actual origin of cargo was outside the remit of this report but this point should be kept in mind. Cargo originating in Guam is checked and signed off before shipment (note that this is a high-risk pathway for the Brown tree snake) but this does not happen anywhere else. Inspection of cargo on arrival in BIOT is carried out by two customs officers who have basic training in biosecurity, however inspections are superficial and do not include unpacking goods. Data on hitch-hiker species detected since 1995 show the prevalence of black and brown widow spiders on fishing vessels, together with a number of vertebrates and large invertebrates of public health and environmental concern, including snails, live snakes, an agamid lizard and a sparrow. Smaller and inconspicuous species, especially invertebrates, would not have been detected and while the numbers and species arriving are unknown, potential pathways of entry clearly exist.

Commodities of potentially high biosecurity risk such as large granite rocks are imported for coastal defence. Samples (40lbs) come in before a main shipment, these are inspected for the presence of soils and contamination, and then stored on a concreted area for a period of c.28 days to check for germination etc. before importation of the main consignment is authorised. It is noted that the samples are often clean while the subsequent main consignment can be contaminated with soil etc. When contaminated aggregate is found it is taken off-shore to be washed. Imported timber now comes in treated, reducing the risk of this particular pathway.

Internal biosecurity is an issue. The primary entry pathway is Diego Garcia where cargo and personnel are regularly transferred both by ship and by air. The 54 Outer Islands are visited by scientists, personnel on Diego Garcia, and occasional private yachts with permission to travel through BIOT. Biosecurity risk mitigation actions are directed at commodities arriving into Diego Garcia, but not to those arriving into the Outer Islands. The Chagos Conservation Trust has developed a draft biosecurity plan for the outer islands based on best practice in New Zealand, which is being applied.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism. BIOT has direct only connections to Bahrain and Singapore, explaining the relative unimportance of the Indian/Asian region as a source of non-native species. Pre-1971 a lot of topsoil came from Bombay, India, which may have resulted in introductions of both non-native plants and invertebrates, particularly soil micro-fauna, but the lack of knowledge on terrestrial invertebrates would result in any such species remaining undetected.

It must be noted that this desk study is broad brush and relatively superficial, time was limited and therefore the information which could be obtained was also limited. Confidence is greater at the higher category level pathways than the lower, subcategory level.

References and Bibliography

Churchyard, T., Eaton, M., Hall, J., Millett, J., Farr, A., Cuthbert, R. and Stringer, C. (2014). The UK's wildlife overseas: a stocktake of nature in our Overseas Territories. Sandy, UK: RSPB.

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British Virgin Islands

Executive summary

- Points of entry to BVI are several with direct access from a number of other countries within the Caribbean region both by air and sea.
- Pathway analysis was done for 148 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For plants, escape from confinement was the commonest pathway of entry.
- The pet trade is the probable source of most of the vertebrate species.
- Exotic pet and plant ownership is popular and this is a potentially important pathway of entry.
- Most introduced species are not confined to the region and have a widespread geographic distribution, suggesting that global trade is more important than local trade.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*	*	
	Erosion control/ dune stabilization			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			***
	Pet/aquarium/terrarium species		*	
	Forestry			*
	Horticulture			***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*	*	*
	Food contaminant (including of live food)	*		
	Contaminant on plants	**		
	Parasites on plants	*		
	Seed contaminant	*		**
	Timber trade	*		
	Transportation of habitat material	*		*
TRANSPORT – STOWAWAY (4)	Container/bulk	*	*	*
	Machinery/equipment			*
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)	*		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the methods section.

This report presents the results of the pathway analysis for the British Virgin Islands (BVI).

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for BVI by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for BVI in 2014.

Taxon	Total species	Non-native species
Invertebrates	1147	4
Vertebrates	558	19
Plants	1582	Not known

The quality of baseline information in BVI was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Basic

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.cruisetimetables.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- http://www.bvitourism.co.uk/
- Argel Horton, Marine Biologist, Government of BVI
- Arona Fahie-Forbes, Nancy Pascoe, Tessa Smith and other stakeholders met and consulted during the technical mission in February 2018.

Visitor statistics are sourced from:

- Central Statistics Office, Government of the Virgin Islands www.bvi.gov.vg

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Broome, R, Sabir, K, Carrington, S. (2007) "Plants of the Eastern Caribbean" http://ecflora.cavehill.uwi.edu/index.html	Comprehensive, up to date in 2007
	Acevedo-Rodríguez, P. & M.T. Strong. (2007) Catalogue of the seed plants of the West Indies http://botany.si.edu/Antilles/Westindies/	Comprehensive, up to date in 2007

Results

Points of entry

BVI has direct daily flights from a number of countries within the Caribbean region only: Antigua, Barbados, Dominican Republic, Puerto Rico, St. Thomas, St. Kitts & Nevis, St. Lucia and St. Maarten. Private jets and charters can originate from both within and outside the region, with the majority coming from the USA.

Cargo arrives by both sea and air, directly from within the region (Dominica, Dominican Republic, Grenada, Puerto Rico, St. Kitts & Nevis, St. Lucia, St. Thomas, St. Vincent & the Grenadines and Trinidad & Tobago), and also Florida and Guyana. Fresh produce is imported from Dominica, Dominican Republic, Grenada, St. Kitts & Nevis, St. Lucia and St. Vincent & the Grenadines. Approximately seven cargo vessels a month arrive from within the region (St. Vincent and the Grenadines and Dominica). Since the hurricane this has risen from 5 a month, with two more vessels arriving on a monthly basis from Trinidad and Tobago and Dominica.

Ferries arrive from St. John and St. Thomas in the US Virgin Islands, and yachts from within the region and across the Atlantic.

Connectivity is summarised in Table 3.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship	Various	Passengers, crew	412 cruise ships visited in 2015	360,891 cruise ship passengers in 2014
	Ferry	St John St Thomas	Passengers, crew. Note: car ferries	Daily	310,104 passengers, passenger boats and ferries in 2014
	Yacht	Various	Crew		No information
	Cargo ship	Miami via Pto. Rico St Thomas St Lucia Dominica	Crew; fresh produce		Approx. 7 vessels a month.
	Fuel tanker		Crew		No information
	Military vessels		Military crew		No information
	Misc		Oil rigs, miscellaneous vessels		No information
Air	Private jet	Various: global	Passengers	700 - 800	84,389 passengers in 2014, scheduled and chartered flights
	Commercial	Antigua St Martin Pto. Rico Dominican Republic St Kitts	Passengers; cargo, including fresh produce	Various flights daily	
	Medevac				No information

In 2016, a total of 1,124,380 visitors arrived in BVI, comprising 407,764 overnight visitors, 17,511 day trippers and 699,105 cruise ship passengers. For 2015, data is given for passenger movement by category and port of entry. Of 121,326 local passengers (residents and immigrants), 31,669 arrived by air and 89,657 by sea, and of 405,936 visiting passengers (day trippers and overnight visitors), 89,186 arrived by air and 405,936 by sea. There are six ports of entry: one air only, two sea only, and four both air and sea.

With regards current exotic animal and plant ownership, BVI has one private collection of exotic animals, and two plant nurseries which import ornamental plants. Table 4 shows the status of exotic animal and plant presence and ownership.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on BVI
Zoos		1 private collection
Botanic gardens		3 plant nurseries; importation is regulated
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	Importation is regulated
	Reptiles	Red-eared sliders
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits, guinea pigs. Importation is regulated; common species are bred for sale on-island
	Other mammals	Importation is regulated
	Fresh water fish	Importation is regulated; common species are bred for sale on-island
	Marine species	Importation is regulated

Existing non-native species

A total of 148 species met the parameters outlined in the methods section and were analysed, comprising 37 terrestrial invertebrate (34 insects and three arachnids), 8 terrestrial vertebrate (five reptiles, two amphibians and one bird), and 103 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hemiptera 10
- Coleoptera 9
- Lepidoptera 6
- Hymenoptera 4 (all ant species)
- Diptera 3
- Isoptera 1

The number of species considered to have been introduced via pathways of entry at the category level are given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 148 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants and food (primarily fresh produce), transport of habitat material and nursery material (principally related to the presence of soil), and timber. Transport as a stowaway was relatively unimportant, with shipping containers being the most commonly implicated vector, followed by vehicles, and then passengers and their baggage. Two species could have arrived via two pathways at the category level, transport contaminant or stowaway, both ants.

One species, the cactus moth *Cactoblastis cactorum* was deliberately released in nature as a biocontrol agent to control invasive cactus.

Vertebrates were mainly considered to have escaped from confinement, having been introduced by the pet trade; the gecko *Hemidactylus mabouia* and corn snake *Pantherophis guttatus* could also have been introduced as a stowaway in shipping containers, and corn snake could have been introduced as transport contaminants in nursery material.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture, or, less commonly, introduction for agriculture. The second commonest pathway of entry was via transport contaminant, primarily of seed and nursery material; these species are mainly small annual weeds, together with *Cyperus* nut-sedges. Six species could have arrived via two pathways at the category level, three as transport contaminant or stowaway, two as escapes from confinement or release into nature, and one species as escape from confinement or transport contaminant.

Table 5. Pathways of entry for 148 species at the category level

	Invertebrates	**Vertebrates**	**Plants**	**Overall**
Release in nature	1	1	2	4
Escape from confinement	0	6	87	93
Transport – contaminant	31	0	17	48
Transport – stowaway	6	2	3	11

Table 6. Pathways of entry for 148 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	1	1	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	2
	Landscape/flora/fauna “improvement” in the wild	0	0	0
	Medical use	0	0	0
	Release in nature for use (other than above, e.g., fur, transport, medical use)	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	20
	Pet/aquarium/terrarium species (including live food for such species)	0	6	0
	Forestry (including afforestation or reforestation)	0	0	5
	Horticulture	0	0	60
	Ornamental purpose other than horticulture	0	0	8
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	5	1	10
	Food contaminant (including of live food)	10	0	0
	Parasites on animals (including species transported by host and vector)	0	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	20	0	0
	Parasites on plants (including species transported by host and vector)	0	0	0
	Seed contaminant	2	0	12
	Timber trade	7	0	0
	Transportation of habitat material (soil, vegetation)	4	0	8
TRANSPORT – STOWAWAY (4)	Container/bulk	6	2	1
	Machinery/equipment	0	0	5
	People and their luggage/equipment (in particular tourism)	2	0	2
	Vehicles (car, train, …)	3	0	1

Source of non-native species

For BVI, there are several possible points of entry both by land and sea, with direct access from a number of other countries within the Caribbean region. The possible source of non-native species is shown in Table 7, for existing species in terms of their geographic distribution, where data was available.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	0	0	2
Wider Caribbean plus Americas	6	3	5
Americas (not wider Caribbean)	3	0	0
Asia/Oceania only	0	0	0
Other combination	0	0	3
Widespread	26	2	92

The majority of all existing non-native species of all taxa have a widespread geographic distribution. A small number of invertebrate species are known from the wider Caribbean region plus mainland Americas. Note that for plant species, geographic distribution is less informative as most introductions are intentional.

Discussion

The majority of terrestrial invertebrates are considered most likely to have been introduced as transport contaminants, mainly of live plants and fresh produce. Of the 36 species, 19 are taxa associated with live plant material, namely Hemiptera or Lepidoptera, together with three species of Dipteran leaf miner and Tephritid fruit fly. The other terrestrial invertebrates consist of nine species of Coleoptera, three Arachnids (all spiders), three species of tramp ant and a termite. The relatively low number of species which are considered most likely to have arrived as transport stowaways is surprising in view of the relatively high connectivity and large visitor numbers of BVI. BVI has direct access with at least nine other Caribbean countries, and direct flights to Miami are expected to start soon, while large numbers of yachts and cruise ships visiting each year. As only data recorded from 1980 was used for this analysis it is possible that species most likely to arrive this way had already done so by then.

Deliberate introduction for horticulture or agriculture is the main pathway of entry of plant species, which then escape from gardens or agricultural areas. Introduction as seed and nursery material contaminant was also important. The technical mission carried out in February 2018 to advise on post-hurricane biosecurity found that the existing nursery owners manage live plant imports very responsibly. Despite this, three species of economically and socially harmful pests were identified which may have been introduced on plant material post-hurricane: the soft scale *Philephedra tuberculosa*, croton scale *Phalacrococcus howertoni* and Cardin's whitefly *Metaleurodicus cardini.*

The pet trade is the probable source of most of the vertebrate species. Five of the eight vertebrate species are reptiles. Exotic pet ownership is popular and this is considered an important pathway for BVI. The African house gecko and flowerpot snake probably arrived as transport stowaway and contaminant, respectively, while the corn snake could have arrived via a number of different pathways, escaped pet, transport stowaway or contaminant.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated, suggesting that for BVI local trade is not as important as trade outside the Caribbean region as the main ultimate pathway of introduction. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

References

Churchyard, T., Eaton, M., Hall, J., Millett, J., Farr, A., Cuthbert, R. and Stringer, C. (2014). The UK's wildlife overseas: a stocktake of nature in our Overseas Territories. Sandy, UK: RSPB.

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Cayman Islands

Executive summary

- Points of entry to the Cayman Islands are several, with direct access from a number of other countries both outside and within the Caribbean region both by air and sea.
- Pathway analysis was done for 178 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For vertebrates, birds were more likely to be intentional introductions, and reptiles and amphibians as unintentional, mainly as transport contaminants.
- For plants, escape from confinement was the commonest pathway of entry.
- Live plants are clearly implicated as an important pathway for both non-native invertebrates and vertebrates.
- Exotic pet ownership is potentially considered an important pathway for the Cayman Islands.
- Most introduced species are not confined to the region and have a widespread geographic distribution.
- Intra-island biosecurity is a big concern.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*		
	Hunting in the wild		*	
	Landscape/flora/fauna “improvement”			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			***
	Pet/aquarium/terrarium species		*	
	Horticulture			***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	**		**
	Food contaminant (including of live food)	**		
	Parasites on animals	*		
	Contaminant on plants	***	*	
	Seed contaminant	*		*
	Timber trade	*		
	Transportation of habitat material	**		*
TRANSPORT – STOWAWAY (4)	Container/bulk	**	*	
	Hitchhikers on boat	*		
	Machinery/equipment	*		*
	Organic packing material	*		
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)	*		

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for the Cayman Islands.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for the Cayman Islands by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for the Cayman Islands in 2014.

Taxon	Total species	Non-native species
Invertebrates	1992	2
Vertebrates	611	19
Plants	854	243

The quality of baseline information in the Cayman Islands was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.cruisetimetables.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- http://www.seaturtle.org/mtrg/projects/cayman/Cayman_NBAP.pdf

Visitor and cargo statistics are sourced from:

- Economics and Statistics Office, Government of the Cayman Islands http://www.caymanislands.ky/statistics/
- https://www.caymanport.com/

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2. Pre-1980 records for some invertebrate taxa were verified from Askew & Stafford (2008) and Brunt & Davies (2012).

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	The Cayman Islands: Natural History and Biogeography, Volume 71, edited by M. A. Brunt, J. E. Davies; Springer. 1994.	Comprehensive, dated
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Broome, R, Sabir, K, Carrington, S. (2007) "Plants of the Eastern Caribbean" http://ecflora.cavehill.uwi.edu/index.html	Comprehensive, up to date in 2007
	Acevedo-Rodríguez, P. & M.T. Strong. (2007) Catalogue of the seed plants of the West Indies http://botany.si.edu/Antilles/Westindies/	Comprehensive, up to date in 2007

Results

Points of entry

There are two international airports, Grand Cayman and Cayman Brac, with a small airstrip on Little Cayman for local flights. The majority of international flights enter through Owen Roberts International Airport on Grand Cayman. Most Cayman flights depart from the southern and eastern United States. Within the region, there are direct flights from Jamaica, the Bahamas and Cuba.

There are no inter-island ferry services in the Cayman Islands.

Cargo arrives by both ship and plane. Within the region, cargo is flown in from Jamaica and Cuba, as well as Honduras and Florida, USA. Within the Cayman Islands, a tug-towed barge carries containerized freight between the three Cayman Islands.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship	Various	Passengers and crew	620: almost daily	1,711,849 passengers
	Ferry	None	N/A	N/A	N/A
	Yacht	Various	Crew		239 vessels made 7,581 calls around the islands
	Cargo ship		Crew		No information
	Fuel tanker		Crew		No information
	Military vessels		Crew		No information
	Refugee boats	Cuba	Refugees	Up to 100 refugees per year, 20 – 30 pax per boat	Statistics not kept
Air	Private jet	Various	Passengers and crew		No information
	Commercial	USA, Honduras, Panama. Jamaica, the Bahamas, Cuba	Passengers	Numerous flights daily	385,451 passengers
	Cargo	USA, Honduras, Jamaica, Cuba	Crew, cargo		272,604 tons cargo 190,629 tons aggregate
	Medevac				No information

In 2016, a total of 620 cruise ships carrying a total of 1,711,849 passengers visited the Cayman Islands, landing at two locations, Grand Cayman and Cayman Brac, and 239 yachts made 7,581 calls to different harbours around the islands. In the same period 385,451 visitors arrived by air, 99% of which arrived in Grand Cayman, and approximately 75% were from the USA.

Cuban refugee boats are a cause of biosecurity concern and are strongly suspected to be responsible for the arrival of two Cuban rock iguanas caught in Grand Cayman a few years ago.

In 2016, a total of 272,604 tons of cargo was imported, including 222,098 tons of containerized cargo and 10,759 tons of break-bulk. In addition, a total of 190,629 tons of aggregate was imported. Sand and gravel is mainly imported from Mexico, Jamaica, Colombia, Cuba, and Honduras. A barge brings construction sand from Cuba, however the Department of Agriculture is very proactive about biosecurity for this potential pathway. Figures are available for 2009 for the cumulative number of ships trading (61) and in that year 24,358 TEU's (Twenty foot container Equivalent Unit) were imported, including 2,298 vehicles.

With regards current exotic animal and plant ownership, the Cayman Islands have no zoos, or public aquaria. There is one botanic garden, QE II Botanic Garden which occasionally imports plants for sale and propagation. There are five plant nurseries which import ornamental plants and Christmas trees, and one pet shop with two outlets selling a range of exotic mammal, bird and fish species. Table 4 shows the status of exotic animal and plant presence and ownership.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Cayman Islands
Zoos		None
Botanic gardens		One
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	Parrots: Cockatoos, African greys, macaws, parakeets, cockatiels, lovebirds Cage birds: racing pigeons, canaries
	Reptiles	None
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits, guinea pigs, hamsters, gerbils, chinchillas
	Other mammals	None
	Fresh water fish	Goldfish, Siamese flighting fish (*Betta splendeni)*
	Marine species	None

Existing non-native species

A total of 178 species met the parameters outlined in the methods section and were analysed, comprising 69 terrestrial invertebrate (one earthworm, two molluscs, five arachnids and 61 insects), 22 terrestrial vertebrate (10 reptiles, nine birds and three amphibians), and 87 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Coleoptera 31
- Hemiptera 20
- Hymenoptera 3 (all ant species)
- Lepidoptera 3
- Diptera 2
- Isoptera 2

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 178 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants, food (fresh produce or stored products), and transport of nursery and habitat material (principally related to the presence of soil). The transport stowaway pathway was the next commonest, mainly via shipping containers. Seven species could have arrived via two pathways at the category level, transport contaminant or stowaway, all either ants or beetles.

For the relatively large number of introduced vertebrate species, the commonest pathways of entry were escape from confinement (mainly bird species) and transport contaminant (mainly reptile species). Three species has been deliberately introduced: the cane toad for biological control, and the wood duck and mallard duck for hunting. The tropical house gecko probably

arrived as a transport stowaway, in a shipping container. Overall, birds were more likely to be intentional introductions, and reptiles and amphibians as unintentional.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture, or, less commonly, introduction for agriculture. The second commonest pathway of entry was via transport contaminant, primarily of nursery material, followed by seed; these species are mainly grasses and small annual weeds, together with *Cyperus* nut-sedges. One plant species, the monk orchid *Oeceocaldes maculata*, is considered by the Department of Environment to have arrived into the territory unaided, through airborne seeds. Two species could have arrived via two pathways at the category level, as transport contaminant or stowaway (*Cleome viscosa*, Asian spiderflower, and *Cyperus rotundus*, purple nutsedge).

Table 5. Pathways of entry for 178 species at the category level

	Invertebrates	**Vertebrates**	**Plants**	**Overall**
Release in nature	1	3	1	5
Escape from confinement	0	9	69	78
Transport – contaminant	54	9	14	77
Transport – stowaway	21	1	4	26
Unaided	0	0	1	1

Table 6. Pathways of entry for 178 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	1	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	0
	Hunting in the wild	0	2	0
	Landscape/flora/fauna "improvement" in the wild	0	0	1
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	30
	Pet/aquarium/terrarium species (including live food for such species)	0	9	0
	Forestry (including afforestation or reforestation)	0	0	
	Horticulture	0	0	37
	Ornamental purpose other than horticulture	0	0	7
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	12	0	12
	Food contaminant (including of live food)	15	0	0
	Parasites on animals (including species transported by host and vector)	1	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	27	8	0
	Seed contaminant	3	0	5
	Timber trade	9	0	0
	Transportation of habitat material (soil, vegetation)	11	0	3
TRANSPORT – STOWAWAY (4)	Container/bulk	17	1	0
	Hitchhikers on boat	2	0	0
	Hitchhikers on plane	0	0	0
	Machinery/equipment	9	0	2
	Organic packing material	4	0	0
	People and their luggage/equipment (in particular tourism)	4	0	3
	Vehicles (car, train, …)	4	0	0

Recent interceptions

General data is not available. However, recently, Cuban tree frog juveniles have been intercepted arriving in a container of live plants from Florida, and three different vertebrate species were intercepted from a passenger on a commercial flight from the USA.

The UK's Fera identification service for invasive invertebrate plant pests (Reid & Malumphy undated) received 86 specimens from the Cayman Islands Department of Agriculture for identification, from interceptions made between April 2010 and March 2011. They recorded 13 Hemipteran species for the first time in the Cayman Islands, seven intercepted on live plants and six on fresh produce.

Source of non-native species

For the Cayman Islands, there are several possible points of entry both by land and sea, with direct access from a number of other countries within the Caribbean region as well as the USA and Canada. The possible source of non-native species is shown in Table 7, for both existing species and recent interceptions, in terms of their geographic distribution.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	5	3	1
Wider Caribbean plus Americas	5	3	6
Americas (not wider Caribbean)	6	3	1
Europe only	0	1	0
Africa only	0	0	0
Asia/Oceania only	1	0	0
Other combination	4	3	4
Widespread	43	9	73

The majority of all existing non-native species of all taxa have a widespread geographic distribution, and this is particularly true for plants. A small number of invertebrate species are known from the wider Caribbean region plus mainland Americas. As many non-native vertebrate species have a regional distribution as are widespread; bird species tend to be widespread while reptile species tend to be regional. Note that for bird and plant species, geographic distribution is less informative as most introductions ae intentional.

Discussion

The majority of terrestrial invertebrates are considered most likely to have been introduced as transport contaminants, mainly of live plants and associated soil (nursery material and habitat material), or as food contaminants, namely of fresh produce or dried stored produce. Taxonomically, species most likely to have arrived as transport contaminants tend to be Hemiptera, Lepidoptera, Isoptera, molluscs and the earthworm, while stowaways tend to be Diptera (tiger mosquito) and Arachnids, while the beetles (Coleoptera) and ants (Hymenoptera) are split between the two.

Internal biosecurity considered in the form of four species of beetle of the genus *Diastolinus,* endemic to specific islands in the Cayman Island group and which are being introduced to others.

Deliberate introduction is the main pathway of entry of plant species, which then escape from gardens or agricultural areas. Introduction as a contaminant of seed or nursery material was also important.

The pet trade is the probable source of about half of the vertebrate species, specifically seven of the nine species of bird, and the two species of *Trachemys* turtle. The other two species of bird are both ducks, probably introduced for hunting. All bird species are considered to have been intentional introductions. Apart from the two turtles mentioned before, all the other eight reptile species are considered most likely to have been unintentional introductions, as

transport contaminants – mainly of live plants – or, in the case of the tropical house gecko, as a stowaway in shipping containers. Exotic pet ownership is popular and this is potentially considered an important pathway for the Cayman Islands. Live plants are clearly implicated as an important pathway for both non-native invertebrates and vertebrates. The two interceptions noted confirm the importance of live plants as a pathway for exotic amphibians, and smuggling of reptiles for the pet trade.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated, suggesting local trade is more important than trade outside the wider Caribbean region (including the rim countries) as the main ultimate pathway of introduction. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

Internal biosecurity is a big issue in the Cayman Islands. Frequent boat traffic occurred between Cayman Brac and Little Cayman, and transport between the islands does not pass through Customs or Immigration inspection so it is hard to control biosecurity at that level. There is one documented case and other anecdotal indications and indirect evidence with all points to repeated unintentional transport of green iguanas from Grand Cayman to both Cayman Brac and Little Cayman.

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Falkland Islands

Executive summary

- Points of entry to the Falkland Islands are relatively few, with direct access from Chile, Uruguay, UK and Cape Verde.
- Pathway analysis was done for 223 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant of live plants.
- For vertebrates, the commonest pathways of entry was escape from confinement.
- Exotic pet ownership is not now considered an important pathway for the Falklands.
- The main pathways of introduction for plants: escape from confinement and as transport contaminant of habitat material and seeds.
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*		
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)		*	*
	Horticulture			***
	Ornamental purpose			**
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*		*
	Food contaminant (including of live food)	*		
	Contaminant on animals			*
	Parasites on animals	*		
	Contaminant on plants	**		
	Seed contaminant	*		***
	Timber trade	*		
	Transportation of habitat material	**		***
TRANSPORT – STOWAWAY (4)	Container/bulk	***		
	Hitchhikers on boat	*		
	Machinery/equipment	*		*
	People and their luggage/equipment	*		
	Vehicles (car, train, …)	*		

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for the Falkland Islands.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for the Falkland Islands by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for the Falkland Islands in 2014.

Taxon	Total species	Non-native species
Invertebrates	1,315	48
Vertebrates	249	17
Plants	1,496	271

The quality of baseline information in the Falklands was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- Falkland Island Government http://www.fig.gov.fk/

Visitor statistics are sourced from:

- Falkland Island Government Statistical Year Book 2014 (http://www.fig.gov.fk/policy/index.php/component/jdownloads/finish/5-statistics/67-statistical-year-book-2014-without-infographics/0?Itemid=0)

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Records of plants were checked in Moore and Sladen (1965) and in Robinson (1984) for insects to remove species recorded before 1980.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Lavery 2017	Up to date for this taxonomic group (arachnids)
	Jones 2011	Up to date in 2011; insects only
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Upson and Lewis 2014	Up to date and comprehensive in 2014

Results

Points of entry

There is a military airport and harbour on East Falkland. There are two scheduled military flights a week from the UK currently via the Cape Verde Islands of West Africa; previously these flights came via Ascension Island. There is also a weekly commercial flight from Punta Arenas, Chile. Travel within the islands is by small plane, interisland ferry or charter boat.

Cargo arrives by both ship and plane. By sea, cargo arrives via a RORO/Container link with the UK. Sea cargo arrives monthly from Uruguay which serves as a hub for containers from all over the world, and a less frequent service from Chile. Cargo arrives by air from both the UK and Chile.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum (vessels)	Stats/trip (passengers)
Sea	Cruise ship	Various	Passengers and crew	106 visits	90,541 passengers, staff and crew
	Ferry	Inter-island	Passengers and crew	None	None
	Yacht	Various	Passengers and crew	61 visits	250 passengers and crew (Estimated figure)
	Cargo ship	Uruguay, Chile, UK	Crew	122 visits	1850 crew (Estimated)
	Fuel tanker	Various	Crew	42 visits	630 crew (Estimated
	Military vessels	Various	Crew	27 visits	1,000 crew (Estimated)
	Fishing vessels	Various	Crew	476 visits	28,560 crew (Estimated) Most crew do not disembark in FI – not allowed shore leave whilst visiting
	Misc, Oil, BAS		Crew	68 visits	1,020 (Estimated)
Air	Private jet	South America	Passengers and crew	9 (2015)	44 pax (2015)
	Commercial	Chile	Passengers and crew	Weekly 53 visits	4,522
	Military	UK via Cape Verde	Passengers and crew	Twice a week 102 visits	13,274
	Cargo	UK,	Crew, cargo	No information	No information
	Medevac	Chile	Crew	22 visits	110 crew (Estimated) Crew remain airside therefore do not enter FI

In 2016, a total of 17,796 people arrived by air on either commercial or military flights and a total of 123,851 people arrived by sea, although many of the latter were crew of fishing vessels, fuel tankers and military vessels who don't leave the ship. There were a total of 106 cruise ship visits with 90,541 passengers, crew and staff.

With regards current exotic animal and plant ownership, there are no zoos or botanic gardens importing exotic plants. There is a garden centre in Stanley, Stanley Nursery and Garden Centre, as well as a hydroponics market garden business, Stanley Growers, which has a long history of introducing off-the-shelf biological control agents from the UK on a yearly basis to control greenhouse pests. The owners regularly visit the UK to buy stock. Stanley Growers also serves as a pet shop, importing tropical fish, hamsters and guinea pigs on demand for the pet trade.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Falklands
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	Parrots & cage birds are present as pets
	Reptiles	No official protocol but anecdotal evidence there are Terrapins as pets- smuggled or imported prior to regulation.
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	Dogs, cats, rabbits, hamsters, guinea pigs
	Other mammals	None
	Fresh water fish	Tropical freshwater fish only
	Marine species	None

Existing non-native species

A total of 223 species met the parameters outlined in the methods section (confirmed records of terrestrial non-native species not recorded prior to 1980) and were analysed, comprising 61 terrestrial invertebrate (33 insects, 25 arachnids, two molluscs and one myriapod), two terrestrial vertebrate (one mammal and one bird), and 160 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Coleoptera 15
- Diptera 7
- Lepidoptera 4
- Hemiptera 2
- Hymenoptera 2
- Orthoptera 2
- Dermaptera 1

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 223 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants and food (primarily fresh produce), followed by habitat material (eg compost, aggregate, etc.). A large proportion of the spiders are considered to have arrived as transport stowaways, in shipping containers. Seven species could have arrived via two pathways at the category level, transport contaminant or stowaway, namely the earwig, general domestic pest species, the centipede and some spiders. One hoverfly (*Eristalis (Eoseristalis) croceimaculata)* considered by Wakeham-Dawson et al to have been blown from South America on prevailing winds (Wakeham-Dawson et al 2009). Insufficient information was found for two species to enable pathways to be inferred (the spider *Steatoda bimaculatum* and the beetle *Atheta trinotata*).

Of the two introduced vertebrate species, the reindeer *Rangifer tarandus* was an intentional introduction as livestock for agricultural production, and the cattle egret *Bubulcus ibis* is considered to have flown in unaided, it is a seasonal migrant which has not established and does not breed in the Falklands.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture as garden plants or, less commonly, introduction for amenity planting. Almost as common was introduction as transport contaminant, primarily of habitat material followed by seed. The habitat material implicated includes aggregate and compost.

Four species could have arrived via two pathways at the category level, as transport contaminant or transport stowaway.

Table 5. Pathways of entry for 223 species at the category level

	Invertebrates	**Vertebrates**	**Plants**	**Overall**
Release in nature	2	0	0	2
Escape from confinement	0	1	81	82
Transport – contaminant	39	0	78	117
Transport – stowaway	24	0	4	28
Corridor	0	0	0	0
Unaided	1	1	0	2

Table 6. Pathways of entry for 223 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	2	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	0
	Hunting in the wild	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	1	7
	Pet/aquarium/terrarium species (including live food for such species)	0	0	0
	Forestry (including afforestation or reforestation)	0	0	0
	Horticulture	0	0	62
	Ornamental purpose other than horticulture	0	0	12
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	1	0	6
	Food contaminant (including of live food)	10	0	0
	Contaminant on animals	0	0	1
	Parasites on animals (including species transported by host and vector)	2	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	15	0	0
	Seed contaminant	1	0	26
	Timber trade	4	0	0
	Transportation of habitat material (soil, vegetation)	12	0	52
TRANSPORT – STOWAWAY (4)	Container/bulk	22	0	0
	Hitchhikers on boat	3	0	0
	Hitchhikers on plane	0	0	0
	Machinery/equipment	4	0	5
	Organic packing material	0	0	0
	People and their luggage/equipment (in particular tourism)	3	0	0
	Vehicles (car, train, …)	6	0	0

Recent interceptions

Some data for interceptions is available from 2007 to 2017 for species collected for identification purposes; note that this data does not include all interceptions, particularly for commonly intercepted species for which identification is already confirmed. Identification to species level is variable but data can be analysed at the higher taxonomic level, noting arachnid, mollusc, annelid and insect Order. A total of 98 interceptions were made (67 insects, 27 arachnids, three molluscs and one earthworm), mostly of individual specimens, and there were two intentional introductions of a biocontrol agent, both Tachinid flies, to control the introduced invasive earwig. Taxonomic breakdown of intercepted insects is as follows:

- Coleoptera 21
- Diptera 11
- Hymenoptera 10

- Hemiptera 9
- Lepidoptera 7
- Orthoptera 4
- Psocoptera 2
- Neuroptera 1
- Collembola 1
- Thysanura 1

Excluding the intentional introduction, 17 interceptions were made on commodities which had arrived by air and 75 by sea: six were unclear. Vectors for the air pathway were just two, fresh produce and one case of live plant material for propagation (Iris bulbs). Vectors for the sea pathway were more varied, including fresh produce, cereal-based dried produce, shipping containers, vehicles (both containerised and break-bulk), habitat material (eg sand), machinery and equipment, wood, pallets, personal goods, plastic packaging material, and souvenirs for local sale. Overall, the great majority of interceptions were made from fresh produce (58), followed by vehicles (9), other (8; assorted goods such as items for the gift shop) and wood (7).

Pathway of introduction broken down by taxonomic group is shown in Table 7. The pathway of transport contamination of food has been split into fresh produce and cereal-based dry foods.

Of the Lepidoptera, all identified species were either *Pieris* spp, or *Plutella xylostella*, both brassica specialists and the commonest fresh produce listed were brassicas, mostly savoy cabbage. Hymenoptera found were mostly wasps or bees; ants (*Ochetellus* spp.) were intercepted on a yacht bound from Australia (non-stop) and a single ant of unknown species was imported among building materials from Uruguay. Of the 27 spiders, six were species of *Steatoda* (*S. nobilis*, *S. grossa* or unidentified to species level).

In addition to the invertebrates, a European common frog *Rana temporaria* was found alive in a garden in Stanley in August 2017. It was not possible to ascertain how or when the frog arrived in the Falklands, but it is presumed that the frog was a stowaway in a container among imported goods. Other vertebrate introductions include a Mexican free-tailed bat *Tadarida brasiliensis* which arrived in a container from Uruguay, mice in chicken food, and a gecko which was accidentally imported in a suitcase from Ascension Island.

In addition to the data from species collected for identification purposes shown in Table 7, data exists from biosecurity inspection of imported vehicles. Between November 2015 and September 2017, 809 vehicles were imported from the UK and 13.4% failed the inspection. Of these, 94% had organic material (mud, leaves, seeds, bird faeces) on the exterior, interior or tray of the vehicle and 11% had living arthropods or signs of them such as webbing. Note that this data doesn't include relatively small interceptions which could be easily dealt with during inspection, such as spraying a live spider with insecticide, removing a harlequin ladybird, picking off odd leaves or seeds, etc.

Table 7. Pathway of introduction of 98 recent interceptions, broken down by taxonomic group.

Interception	Pathway*									
	BIO	**PRO**	**CER**	**PLA**	**HAB**	**CON**	**MAC**	**WOO**	**VEH**	**OTH**
Annelida		1								
Molluscs					1			2		
Arachnids		10			1	3	1	2	7	4
Insects:										
Coleoptera		14	1			2		2		1
Diptera	2	10							1	
Hymenoptera		5			2		1			
Hemiptera		6		1	1				1	
Lepidoptera		7								
Orthoptera		2						1		1
Psocoptera		1								
Neuroptera		1								
Collembola		1								
Psocoptera			1							1
Thysanura										1
TOTAL	1	58	2	1	5	5	2	7	9	8

*BIO = biocontrol agent, PRO = fresh produce, CER = cereal-based foodstuffs, PLA = live plant material for propagation HAB = habitat material, CON = shipping containers, MAC = machinery and equipment, VEH = vehicles, WOO = wood, including pallets, OTH = other. “Other” includes plastic packaging, imported souvenirs for local sale.

Source of non-native species

For the Falkland Islands there are relatively few possible points of entry both by land and sea, with direct access only from Chile, Uruguay, UK, Cape Verde and South Georgia/Antarctica. The possible source of non-native species in terms of their geographic distribution is shown in Table 8.

Table 8. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
South Americas only	12	0	2
North Americas only	3	0	3
North and South Americas only	1	0	2
UK/Europe only	4	0	25
Africa only	0	0	0
Asia only	0	0	1
Other combination	7	1	41
Widespread	28	1	83

A large proportion of “other combination” consists of Europe plus North America (five of the seven invertebrate and 24 of the 41 plant species), or circumpolar / circumboreal distribution (a further seven plant species).

The geographic origin of the recent interceptions in Table 7 is known with more precision, and is given in Table 9. Commodities listed as originating in China or Japan came via the UK in both cases.

Table 9. Geographic origin of recent interceptions.

Source	Invertebrates	Vertebrates
Chile, Uruguay, Brazil	49	0
USA	3	0
UK/Europe	43	1
China/Japan	2	0

The majority of all existing non-native species of all taxa have a widespread geographic distribution, suggesting local trade is not important as the main ultimate pathway of introduction. Note that for plant species, geographic distribution is less informative as a large proportion of introductions are intentional.

Discussion

The Falklands are in a state of flux in terms of economic drivers and this will be seen in changing priorities in terms of pathways of entry. Oil was discovered in 2010 and production for the world markets planned for 2019. The traditionally important agricultural sector is being superseded by the growing fisheries industry, with tourism also increasing after a long lull as the global economy picks up (Falkland Islands Government, 2015). There is no forestry in the islands.

Coleoptera, the beetles, are the commonest insect Order for both the existing invertebrates and recent interceptions, with Diptera and Hymenoptera a close third or second. Of the 22 recently intercepted species with confirmed identification to species level, eight are in the existing species database and 14 are apparently new to the islands, not being included in the complete RSPB stock take database or CABI Invasive Species Compendium for species introduced before and after 1980. This is a very high proportion of new species arriving in the Falklands. Fresh produce was the main vector of recent interceptions. Some species were intercepted from fresh produce for which this pathway not expected or not considered the most likely one, for example the hoverfly *Eristalis croceimaculata*, various beetles, ladybirds and spiders. The original introduction of *E. croceimaculata* is considered to have been unaided, blown over naturally, but individuals are clearly also arriving with fresh produce. A lot of spiders in the existing species database are considered most likely to have arrived as stowaways in shipping containers or vehicles, but large numbers of interceptions arrived in fresh produce as well as via vehicles. The transport contaminant – food contaminant pathway has possibly been underestimated for existing species.

Conclusions drawn from data for recent interceptions may be an artefact of searching effort. Inspection rates are higher for fresh produce and vehicles (100%) than for other commodities such as containers with building materials (70%), goods for the gift shop (occasional and especially if originated in China) or personal effects (spot checks mainly carried out by Customs). In addition to biosecurity inspections at the border, some things are also brought in or reported by public, especially spiders.

Inferred pathways in the existing species database were adjusted to include the known interception pathway in the five cases where this was not already included. Note that intercepting a species in one pathway doesn't necessarily mean that this is the only or the original pathway of introduction for that species, and other pathways are left ticked where other evidence (for example, from the CABI Invasive Species Compendium or interception data for other Territories) suggests these are also highly likely pathways.

Vertebrates have been mainly intentional introductions in the past, but this is now a regulated pathway. The recently intercepted European frog was most likely a stowaway and other interception data (bat, mice, gecko) clearly indicates the importance of this pathway for vertebrates.

Three main pathways of introduction are implicated for plants: escape from confinement following introduction for horticulture, as transport contaminants of habitat material, and as transport contaminants of seeds. Habitat material consists of two main groups: aggregate, and organic material such as composts. Seed contaminant species are mainly small, annual species and grasses. Only introduction for horticulture can be regulated as an intentional introduction, and clearly transport contaminant is an important pathway.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread. Many species have a northern distribution, suggesting the UK / North America route is the main one. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism; recent outbreaks of cockroaches have been linked to the importation of equipment from Zimbabwe.

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Gibraltar

Executive summary

- There are many possible routes of entry to Gibraltar, with a land bridge to mainland Europe.
- Pathway analysis was done for 66 existing non-native species that were first recorded since 1980.
- Only three species of invertebrate were recorded, with pathways of entry as transport contaminant of live plant material plus one biological control agent.
- The pet trade is the main pathway of entry of non-native vertebrates.
- The main pathway of introduction for plants was as garden plants.
- Most plant species have a widespread geographic distribution, while vertebrates have a more varied distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*		
ESCAPE FROM CONFINEMENT (2)	Pet/aquarium/terrarium species		*	
	Horticulture			***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material			**
	Contaminant on plants	*		
	Seed contaminant			*
	Transportation of habitat material			*
TRANSPORT – STOWAWAY (4)	Container/bulk			*
	Hitchhikers on boat		*	
	Machinery/equipment			*
	Organic packing material			
	People and their luggage/equipment			*
	Vehicles (car, train, …)			*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the separate document “Pathway analysis – methods”.

This report presents the results of the pathway analysis for Gibraltar.

Baseline

The quality of baseline information in Gibraltar was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- Gibraltar Port Authority http://www.gibraltarport.com/
- Gibraltar International Airport http://www.gibraltarairport.gi/
- Royal Air Force Gibraltar https://www.raf.mod.uk/rafgibraltar/
- Royal Navy https://www.royalnavy.mod.uk/news-and-latest-activity/operations/mediterranean-and-black-sea/gibraltar-squadron

Visitor statistics are sourced from:

- HM Government of Gibraltar Statistics Office, Tourism Survey Report 2016 https://www.gibraltar.gov.gi/new/sites/default/files/HMGoG_Documents/Tourist%20Survey%20Report%202016.pdf

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005
Plants	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005
	http://floraofgibraltar.myspecies.info/	Contains most species, with general descriptions

Results

Points of entry

There is an international airport served by three airlines, British Airways, EasyJet and Royal Air Maroc, from the UK and Morocco. Cruise ships dock at the Gibraltar Cruise Terminal and for yachts there are three commercial marinas, and a new berthing facility for super yachts at the Mid-Harbour Marina which is managed by the Port Authority.

In 2016, a total of 10,115,241 visitors arrived in Gibraltar, 231,071 by air, 420,579 by sea and 9,463,591 by land. Of those which arrived by sea, 404,005 came by cruise ship and 16,305 by yacht, with 269 “other”. Of those which arrived by air, 93,289 were staying in Gibraltar (for an average of 2.2 days) and 137,782 were in transit. Of those which arrived by land, 6,838,791 were non-Gibraltarian workers. A total of 2,620,203 vehicles and 6,931 coaches crossed the land border.

By nationality, 71% of excursionists by land were Spanish, 13% were British and 13% were other EU nationals; 46% of excursionists arriving by coach were British and 36% were other EU nationals (excluding UK and Spanish nationals); and 86% of cruise liner excursionists were British and 9% were other nationalities.

Royal Air Force Gibraltar has an airfield but no military aircraft permanently based there. The Royal Navy operates two Fast Patrol Boats of the Royal Navy's Gibraltar Squadron, HMS Sabre and HMS Scimitar.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Vessels	Cruise ships	Various	Passengers and crew	All year round	404,005 pax
	Yachts	Various	Crew	All year round	16,305 pax
	Cargo ships	Various	Crew	4173	508 came alongside
	Military vessels	2 based in Gibraltar	Crew		
Air	Commercial flights	UK, Morocco	Passengers		231,071 pax
	Cargo flights	No information	Crew	No information	
	Private jets	Various	Crew	No information	

Cargo vessels of the shipping company Oldenburg-Portugiesische Dampfschiffs-Rhederei, or OPDR dock at the container berth. The number of cargo vessels with dry cargo visiting in 2016 was 4173. Of these 508 came alongside and 420 were classed as Off Port Limits or Sea Drifting outside BGTW. The purpose of call ranged from Bunkers, Detention, Cargo loading/unloading/sampling, Charts, Class Survey, Crew Change, Debunkers, Laid Up, Medical Assistance, Owners Change, Provisions, Repairs, Shelter, Slops Discharge, Spares, Stores, STS, Surveyor Transfer, Underwater Cleaning/inspections/survey, Waiting Orders and Yacht Loading/unloading. Flag State of vessels visiting was split as follows:

UK/Isle of Man	130
EU	857
Rest of the World	3186

With regards current exotic animal and plant ownership, the Alameda Wildlife Conservation Park has a collection of exotic and native species which began in 1994 as a collection of parrots, land tortoises and monkeys all confiscated from illegal traders who were passing through Gibraltar (http://www.awcp.gi/our-history). There are two pet shops, the Pet Zone and the Tropical Aquaria Petshop.

Alameda Gardens became the Gibraltar Botanic Gardens in 1991 when Wildlife (Gibraltar) Limited, a firm of Environmental Consultants and Managers was contracted by the Government of Gibraltar to manage the gardens and convert them into the Gibraltar Botanic Gardens, with both native and exotic plant species planted (http://www.gibraltar.gi/nature/?language=en&category=1&item=4). There is also one garden centre importing exotic plants for sale.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence in Gibraltar
Zoos		Alameda Wildlife Conservation Park: exotic and native species
Botanic gardens		Gibraltar Botanic Gardens opened in 1991: exotic and native species
Public aquaria	None	
Pet ownership:	Parrots and cage birds	A wide range of species kept as pets
	Reptiles	A wide range of species kept as pets
	Other	Insects kept as both pets and live pet-food, and arachnids kept as pets
	Amphibians	A wide range of species kept as pets
	Domestic cats, dogs, rodents, lagomorphs	A wide range of species kept as pets
	Fresh water fish	A wide range of species kept as pets
	Marine species	At least some species kept as pets

Existing non-native species

A total of 66 species met the parameters outlined in the methods section and were analysed, comprising three terrestrial invertebrates (all insects), 12 vertebrates (nine birds and three reptiles) and 51 terrestrial plant species.

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 66 as some species have several possible pathways of entry.

The non-native invertebrate species recorded consist of two Hemipteran insects, the 2-spotted leafhopper *Sophonia orientalis* and flatid leafhopper *Metcalfa pruinosa*, both considered most likely to have been introduced as transport contaminants of live plant material. The third species in the parasitic wasp *Neodryinus typhlocybae* intentionally introduced as a biological control agent for the flatid leafhopper.

The majority of introduced vertebrates are birds. Five were introduced as pets, one, the house crow *Corvus splendens* is recorded to have arrived as a transport stowaway, hitchhiking on a ship in 1991, and three are transatlantic vagrants and most likely arrived as ship-assisted wild birds.

For plants, the commonest pathway of entry was introduction for horticulture as garden plants. Following this was introduction as transport contaminant of nursery material, associated with soil or plant pots, or as seed contaminants.

Table 5. Pathways of entry for 66 species at the category level

	Invertebrates	Vertebrates	Plants	Overall
Release in nature	1	0	0	1
Escape from confinement	0	8	31	39
Transport – contaminant	2	0	20	22
Transport – stowaway	0	1	3	4
Corridor	0	0	0	0
Unaided	0	3	0	3

Table 6. Pathways of entry for 66 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	1	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	0
	Hunting in the wild	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	0
	Botanic garden or zoo	0	0	0
	Pet/aquarium/terrarium species (including live food for such species)	0	8	0
	Forestry (including afforestation or reforestation)	0	0	0
	Horticulture	0	0	29
	Ornamental purpose other than horticulture	0	0	2
TRANSPORT – **CONTAMINANT (3)**	Contaminant nursery material	0	0	15
	Food contaminant (including of live food)	0	0	0
	Contaminant on animals	0	0	0
	Parasites on animals (including species transported by host and vector)	0	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	2	0	0
	Seed contaminant	0	0	2
	Timber trade	0	0	0
	Transportation of habitat material (soil, vegetation)	0	0	5
TRANSPORT – **STOWAWAY (4)**	Container/bulk	0	0	2
	Hitchhikers on boat	0	1	0
	Hitchhikers on plane	0	0	0
	Machinery/equipment	0	0	2
	Organic packing material	0	0	0
	People and their luggage/equipment (in particular tourism)	0	0	1
	Vehicles (car, train, …)	0	0	1

Source of non-native species

For Gibraltar there are many possible routes of entry, with a land bridge to mainland Europe and relatively quick access to Mediterranean countries and North Africa. The possible source of non-native species in terms of their geographic distribution is shown in Table 7.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
UK/Europe only	0	2	0
Americas only	0	2	4
Africa only	0	1	7
Other combination	2	5	5
Widespread	0	2	35

The majority of existing non-native plant species have a widespread geographic distribution, while introduced vertebrates have a much more varied current distribution. Data are too few for invertebrates to comment.

Discussion

The very low number of non-native invertebrates recorded is unusual, and as the quality of the database for animals is scored as “Good” it suggests that there really are very few introduced invertebrates in Gibraltar. This may be linked to the lack of agriculture and consequently lack of the large number of non-native species associated with crop plants which are normally recorded. Gibraltar is not an island Territory but geographically part of continental Europe, with presumably a typical continental biodiversity and relative resistance to invasion compared to island biotas.

Most introductions are intentional. The pet trade and horticultural trade for garden plants are clearly important, and these are the two trades of concern. Tourism is the biggest industry in Gibraltar, alongside financial services and shipping, and very large numbers of people, vehicles and vessels come and go continually across the border, which is not tightly regulated for biosecurity, making it easy to import both pets and plants.

As most introductions are deliberate, current geographic distribution of species is not very informative with regard patterns of trade as hobbyists will source desired species regardless of where they are.

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Montserrat

Executive summary

- Points of entry to Montserrat are limited, with direct access mainly within the Caribbean region and predominantly from Antigua.
- Pathway analysis was done for 167 existing non-native species.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For plants, escape from confinement was the commonest pathway of entry.
- Exotic pet ownership is a potential pathway of introduction.
- Fish farming is a new initiative and also presents a potential pathway of introduction.
- Most introduced species are not confined to the region and have a widespread geographic distribution, suggesting that global trade is more important than local trade.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	*		
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)		*	**
	Pet/aquarium/terrarium species		*	
	Forestry			*
	Horticulture			***
	Ornamental purpose			**
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	**		*
	Food contaminant (including of live food)	***		
	Parasites on animals	*		
	Contaminant on plants	***		
	Parasites on plants	*		
	Seed contaminant	*		*
	Timber trade	*		
	Transportation of habitat material	*		*
TRANSPORT – STOWAWAY (4)	Container/bulk	*	*	
	Machinery/equipment	*		*
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)	*		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for Montserrat.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for Montserrat by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for Montserrat in 2014.

Taxon	Total species	Non-native species
Invertebrates	1287	72
Vertebrates	310	17
Plants	978	146

The quality of baseline information in Montserrat was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Some

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.cruisetimetables.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- http://www.visitmontserrat.com/
- Stephen Mendes, Department of Environment, Montserrat

Visitor information was also sourced from:

- https://discovermni.com/2016/02/12/2015-tourism-figures-released/

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
Plants	CABI Invasive Species Compendium	Reasonably comprehensive

Results

Points of entry

Montserrat has no direct flights outside the region and is routinely served by flights from Antigua, around 20 minutes flying time away, with occasional direct flights to St Vincent. Occasional private charters connect to Guadeloupe, Anguilla, Nevis and St. Martin (Dutch side). A weekly helicopter service flies from Antigua to Montserrat Volcano Observatory. Medevac flights go to Guadeloupe, Antigua and Barbados.

A Ferry service connects Antigua to Montserrat four times a week, and can be chartered to St. Kitts and Nevis.

Cargo arrives by both plane and sea; weekly from Dominica with vegetables and other goods, once or twice a Month from Florida with General cargo, and once a month from St. Martin (and UK via St Martin) with general cargo.

Connectivity is summarised in Table 3.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks, with visitor data for 2015.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship	Various	Passengers, crew	14	2,591 passengers
	Cargo ship	Regional Florida	Crew	Weekly	399 calls (include Ferry Visits transporting Cargo (173 recorded))
	Ferry	Antigua		Up to 4 services a day, 4 days a week	8,861 Visitors of which: 4,836 Tourists 1,434 Excursionists
	Yacht	Various	Crew	474 yachts	1,815 passengers and crew
	Fuel tanker		Crew	Depends on rotation and local usage	22 calls
	Military vessels		Military crew	Twice yearly	165 military crew (record from one vessel)
	Misc		Oil rigs, miscellaneous vessels	No data	No data
Air	Private jet		Passengers	None	
	Medevac	Regional	Crew	Occasional	19 (3 In and 16 out)
	Commercial	Antigua, Barbuda	Passengers	Up to 5 flights a day	4,414 Visitors of which: 4,108 - Tourists 306 - Excursionists

With regards current exotic animal and plant collections, Montserrat has no public zoos, public aquaria, and one botanic garden; see Table 4. Fish are typically sourced from Antigua, and there is a movement into fish farming.

Table 4. Exotic animal and plant collections and ownership

Type	Detail	Presence on Montserrat
Zoos		None
Botanic gardens		One
Public aquaria		None
Pet ownership:	Parrots	Around 4 in total
	Other birds	None
	Reptiles	Red footed tortoise Green iguana
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits
	Other mammals	Vervet monkeys
	Fresh water fish	Less than 50 people keep aquarium fish

Existing non-native species

A total of 167 species met the parameters outlined in the methods section and were analysed, comprising 76 terrestrial invertebrate (67 insects, six arachnids, two nematodes and one mollusc), five terrestrial vertebrate (three reptiles, one mammal and one bird) and 85 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hemiptera 29
- Coleoptera 26
- Diptera 5
- Lepidoptera 4
- Hymenoptera 1
- Isoptera 1
- Thysanura 1

The number of species considered to have been introduced via pathways of entry at the category level are given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 166 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport as a contaminant, primarily of live plants, followed by contamination of food, namely fresh produce, and then of nursery material. Seven species could have arrived via two pathways at the category level, transport contaminant or stowaway, all ant species.

Vertebrates were mainly considered to have escaped from confinement, having been introduced by the pet trade; the gecko *Hemidactylus mabouia* could also have been introduced as a stowaway in shipping containers.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture, followed by introduction for agriculture and then as an ornamental purpose other than horticulture. Five species could have arrived via more than

one pathway at the category level: four as transport contaminant or stowaway, and one species as escape from confinement, transport contaminant or transport stowaway.

Table 5. Pathways of entry for 167 species at the category level

	Invertebrates	Vertebrates	Plants	Overall
Release in nature	1	0	0	1
Escape from confinement	1	5	76	82
Transport – contaminant	69	0	10	79
Transport – stowaway	11	1	6	18

Table 6. Pathways of entry for 167 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	1	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	0
	Landscape/flora/fauna “improvement” in the wild	0	0	0
	Release in nature for use (other than above, e.g., fur, transport, medical use)	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks) / Horticulture	0	1	16
	Pet/aquarium/terrarium species (including live food for such species)	0	5	0
	Forestry (including afforestation or reforestation)	0	0	3
	Horticulture	0	0	49
	Ornamental purpose	0	0	12
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	12	0	6
	Food contaminant (including of live food)	21	0	0
	Parasites on animals (including species transported by host and vector)	2	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	41	0	0
	Parasites on plants (including species transported by host and vector)	1	0	0
	Seed contaminant	4	0	4
	Timber trade	9	0	0
	Transportation of habitat material (soil, vegetation)	10	0	4
TRANSPORT – STOWAWAY (4)	Container/bulk	10	1	0
	Machinery/equipment	5	0	6
	People and their luggage/equipment (in particular tourism)	3	0	3
	Vehicles (car, train, …)	1	0	2

Source of non-native species

For Montserrat, possible points of entry are limited, with direct access only from nearby Antigua. The possible source of non-native species is shown in Table 7 for existing species in terms of their geographic distribution, where data was available.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	1	0	2
Wider Caribbean plus Americas	9	2	0
Americas (not wider Caribbean)	1	0	0
Asia/Oceania only	1	0	0
Other combination	2	1	2
Widespread	53	2	82

The majority of all existing non-native species of all taxa have a widespread geographic distribution. A smaller number of invertebrate species are known from the wider Caribbean region plus mainland Americas. Note that for plant species, geographic distribution is less informative as most introductions are intentional.

Discussion

Live plants and food (mainly fresh produce, ie fruit and vegetables) stand out as a historic source of non-native invertebrates, and the biggest taxonomic group of invertebrate species in the database are scale insects (Hemiptera: 37%), which are closely associated with living plant material. The second biggest group (33%) are various species of Coleoptera which account for many of the transport stowaways.

Note that no spiders were recorded in the database; live spiders are frequently intercepted on vehicles and in shipping containers in St Helena.

Deliberate introduction is the main pathway of entry of plant species, as escapes from gardens or agricultural areas. Introduction as seed contaminant was considered to be a minor pathway, suggesting that small annual weed species are not very common on Montserrat.

The pet trade is the source of most if not all of the vertebrate species. Exotic pet ownership remains an issue and is considered an important pathway for Montserrat. The movement into Tilapia fish farming is also a potential pathway for aquatic non-native species.

Regulations now exist to control importations of live plants and animals, and inspect imported produce and plant material; this is handled by trained Customs Officers as there are no dedicated biosecurity officers. However, capacity on-island to carry out a risk assessment of new species is poor. It is possible to import commercially sourced plant seeds with no controls and this is potentially a source of new invasive plant species.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated, suggesting local trade is not as important as trade outside the wider Caribbean region (including the rim countries) as the main ultimate pathway of introduction. Note that

species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

References

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Pitcairn

Executive summary

- Points of entry to Pitcairn are relatively few, with direct access only from New Zealand and the French Polynesia.
- Pathway analysis was done for 197 existing non-native species that were first recorded since 1980.
- For invertebrates, the commonest pathway of entry was as transport contaminant of live plants.
- No new species of non-native vertebrate were introduced since 1980.
- Exotic pet ownership is not considered an important pathway for Pitcairn.
- The main pathways of introduction for plants was escape from confinement, mainly following introduction for horticulture as garden plants.
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Plants
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)		***
	Forestry		*
	Horticulture		***
	Ornamental purpose other than horticulture		*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*	*
	Food contaminant (including of live food)	*	
	Contaminant on plants	*	
	Seed contaminant		**
	Timber trade	*	
	Transportation of habitat material	*	***
TRANSPORT – STOWAWAY (4)	Container/bulk	*	*
	Machinery/equipment		*
	People and their luggage/equipment	*	*
	Vehicles (car, train, …)	*	

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the separate document “Pathway analysis – methods”.

This report presents the results of the pathway analysis for Pitcairn Islands (“Pitcairn”).

Baseline

An overview of numbers of species recorded for Pitcairn by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for Pitcairn in 2014.

Taxon	Total species	Non-native species
Invertebrates	1,091	3
Vertebrates	506	4
Plants	532	228

The quality of baseline information in Pitcairn was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Basic	None

Sources of information

Points of entry

Information for connectivity, visitor statistics and exotic animal and plant ownership were sourced from:

- http://www.visitpitcairn.pn/go_there/claymore_schedule/index.html
- https://www.cruisetimetables.com/cruises-to-anguilla.html

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2. Note that information is limited for invertebrates as noted in the gap analysis, with a baseline for animals scored as none.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005
Plants	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005

Results

Points of entry

There is no airport in Pitcairn and access is entirely by sea. The island is served by a dedicated passenger / cargo vessel, the MV Claymore II, which sails four times a year between New Zealand and Pitcairn to deliver cargo, and also makes eight round trips a year between Pitcairn and the nearest airport in Mangareva in French Polynesia, for passengers.

Oeno was a break away for islanders and was visited annually if the weather/sea conditions were good and local longboats visited Oeno Island from the main island several times a year, but the last visit took place in 2009. From time to time cruise ships and charter vessels may visit Oeno but it is not regular.

Connectivity is summarised in Table 3 for 2017.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Vessels	MV Claymore II	Tauranga, New Zealand	Mainly cargo	4 voyages	12 passengers per trip = 48 a year if full each voyage
		Mangareva, French Polynesia	Mainly passengers	8 voyages	12 passengers per trip = 96 a year if full each voyage
	Cruise ships	Varied	Passengers	Around 9 visits per year	Around 160 passengers
	Yachts	Various, mostly westbound from South America via Galapagos, Easter Island	Crew	26 yachts	74 passengers landed

In the 12 months between September 2017 and September 2018, a total of 9 cruise ships are scheduled to visit Pitcairn, with ca 160 passengers on board. In 2017 a total of 26 yachts visited the islands, from which 74 passengers landed. This compares to 14 yachts with 43

passengers in 2015 and 17 yachts with 40 passengers in 2016. It is noted that yachts are getting bigger, carrying more passengers. All passengers stay on-board overnight.

With regards current exotic animal and plant ownership, there are no zoos, pet shops or botanic gardens or garden centres importing exotic animals or plants.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Pitcairn
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	A couple of households have fresh water turtles (species not known)
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	None
	Other mammals	None
	Fresh water fish	Goldfish, guppies
	Marine species	None

Existing non-native species

A total of 197 species met the parameters outlined in the methods section and were analysed, comprising 13 terrestrial invertebrate (five insects, five arachnids, two molluscs and one crustacean, a woodlouse) and 184 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hymenoptera 2 (both tramp ants)
- Diptera 1
- Hemiptera 1
- Lepidoptera 1

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 197 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly of live plants, and then of nursery material (soil) and food (mainly fresh produce). The second commonest pathway of entry was as transport stowaway, mainly in shipping containers, which included most of the species of spider and the two tramp ant species. The two species of tramp could have arrived via two pathways at the category level, transport contaminant or stowaway.

No non-native species of vertebrate have been introduced since 1980.

For plants, the commonest pathway of entry was introduction was escape from confinement, mainly following introduction for horticulture as garden plants or, less commonly, introduction for agriculture. Less common was introduction as transport contaminant, primarily of habitat material followed by contaminant of seed. The habitat material implicated included aggregate and composts, etc.

Table 5. Pathways of entry for 197 species at the category level

	Invertebrates	**Plants**	**Overall**
Release in nature	0	0	0
Escape from confinement	0	145	145
Transport – contaminant	9	30	39
Transport – stowaway	6	5	11
Corridor	0	0	0
Unaided	0	4	4

Table 6. Pathways of entry for 197 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0
	Hunting in the wild	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	42
	Pet/aquarium/terrarium species (including live food for such species)	0	0
	Forestry (including afforestation or reforestation)	0	1
	Horticulture	0	92
	Ornamental purpose other than horticulture	0	10
TRANSPORT – **CONTAMINANT (3)**	Contaminant nursery material	2	5
	Food contaminant (including of live food)	3	0
	Contaminant on animals	0	0
	Parasites on animals (including species transported by host and vector)	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	7	0
	Seed contaminant	0	15
	Timber trade	1	0
	Transportation of habitat material (soil, vegetation)	1	23
TRANSPORT – **STOWAWAY (4)**	Container/bulk	6	3
	Hitchhikers on boat	0	0
	Hitchhikers on plane	0	0
	Machinery/equipment	0	2
	Organic packing material	0	0
	People and their luggage/equipment (in particular tourism)	2	4
	Vehicles (car, train, …)	3	0

Two species of plant could have arrived via two pathways, transport contaminant or transport stowaway, *Cyanthillium cinereum* little ironweed and *Taraxacum officinale* dandelion. The sea bean *Mucuna gigantean* and beach naupaka *Scaevola taccada* are considered most likely to have arrived unaided by marine currents, and the two nightshades *Solanum americanum* and *S. nigrum* unaided via avian vectors. Insufficient information was available for two species of plant to infer pathway, the sticky daisy *Adenostemma lavenia* and *Corchorus echinatus*.

Source of non-native species

For Pitcairn there are relatively few possible points of entry both by land and sea, with direct access only from New Zealand and French Polynesia. The possible source of non-native species in terms of their geographic distribution is shown in Table 7.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Plants
Americas only	0	1
Oceania only	0	4
Oceania plus rim countries only	0	5
Other combination	4	9
Widespread	9	164

The majority of all existing non-native species of all taxa have a widespread geographic distribution, suggesting local trade is not important as the main ultimate pathway of introduction; also that the non-native species present on Pitcairn tend to be cosmopolitan species. Note that for plant species, geographic distribution is less informative as a large proportion of introductions are intentional.

Discussion

Agriculture is important for Pitcairn as people rely heavily on local production between visits by the single supply vessel.

The commonest inferred pathway for existing non-native invertebrate species was mostly as a transport contaminant of live plants followed by fresh produce and nursery material, with soil being implicated in the latter case. Introduction as a transport stowaway was also of some importance, mainly of shipping containers, vehicles and people and baggage. As Pitcairn doesn't have the facilities for containerised cargo, shipping containers are implicated for the transport of species further up the line, with transference to break bulk and smaller packages for the last leg.

As data is very limited these findings must be taken as inconclusive, although they match the results from other territories with much larger non-native invertebrate databases.

The main pathway of introduction implicated for plants is deliberate introduction for horticulture, agriculture and amenity planting, and these pathways clearly require regulation. Transport contamination of habitat material (aggregate, composts, etc) is also important although less so. Introduction via transport stowaways was not considered important for the existing non-native plant species in Pitcairn.

Internal biosecurity is of concern for Pitcairn. The permanent population live on the main island, they used to visit Oeno islands on a regular basis as a retreat and occasionally bring tourists to camp. Henderson is a World Heritage Site and biosecurity protocols exist. A draft Environmental Protection Ordinance is in its final stage with some further work to be carried out. The Division Manager will complete a final review of the document before it is approved by the Island Council and Governor's Office. The Ordinance will give the Bio Security Department powers to search, seize and destroy. Public consultation has been carried out. Only two non-native plant species are noted to only occur on Henderson Island, *Passiflora maliformis* and *Setaria verticillata*. The other islands in the group are not recorded to have non-native species which don't occur on the main island.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and researchers.

It must be noted that this desk study is broad brush and relatively superficial, time was limited and therefore the information which could be obtained was also limited. Confidence is greater at the higher category level pathways than the lower, subcategory level.

References

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South Georgia and the South Sandwich Islands

Executive summary

- Points of entry to SGSSI are relatively few, with direct access only from the Falklands and the UK.
- Pathway analysis was done for 34 existing non-native species..
- For invertebrates, the commonest pathway of entry was as transport contaminant of food, mainly fresh produce.
- No new species of non-native vertebrate were introduced since 1980.
- The main pathways of introduction for plants was transport stowaway, in equipment or in personal baggage.
- The UK/Europe is strongly implicated as the source of most non-native species.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Plants
TRANSPORT – CONTAMINANT (3)	Food contaminant (including of live food)	*	
	Transportation of habitat material	*	
TRANSPORT – STOWAWAY (4)	Container/bulk		**
	Hitchhikers on boat	*	
	Machinery/equipment	*	**
	People and their luggage/equipment		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for South Georgia and the South Sandwich Islands (SGSSI).

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for SGSSI by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for SGSSI in 2014.

Taxon	Total species	Non-native species
Invertebrates	2,191	8
Vertebrates	213	4
Plants	675	23

The quality of baseline information in SGSSI was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- https://www.bas.ac.uk/polar-operations/sites-and-facilities/facility/king-edward-point/

Visitor statistics are sourced from:

- Government of South Georgia and the South Sandwich Islands. Annual Report 2016. https://www.gov.gs/docsarchive/GSGSSI/Annual%20Reports/Annual%20report%202016_FINAL.pdf

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005
	Key & Key (2009)	Detailed survey in 2009
Plants	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Varnham (2005) Annex 4	Comprehensive from published data sources, up to date in 2005
	GSGSSI (2016)	Comprehensive in 2016

Results

Points of entry

There is no airport on SGSSI and access is entirely by sea and is strongly seasonal due to the extreme weather over the winter season. There is also no permanent population, although there is a small transient population of researchers varying from 10 people over winter to 20-40 people over summer.

The supply vessel RRS *Ernest Shackleton* supports operations on South Georgia as part of the British Antarctic Survey fleet, travelling between the Falklands and South Georgia once in the region.

The fishery inspection vessel MV Pharos SG spends the summer season patrolling the maritime zone, calling in at Kind Edward Point, and also making regular visit to the Falklands to exchange crew and fisheries observers, and to resupply. All fishery vessels are inspected at King Edward Point before being licenced.

In the 2015/2016 season, 8,780 cruise ship passengers visited SGSSI, on a total of 68 cruise ships and 22 yacht visits with passengers from 63 countries. Most tourism is ship-based, but a limited amount of camping is allowed on shore and in 2016 a total of 11 expeditions were undertaken around the ‘Shackleton Traverse Route’.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	RRS *Ernest Shackleton* / James Clarke Ross	UK, Falklands	Crew, researchers, cargo	2-4	
	Fishery patrol vessel MV Pharos SG	King Edward Point, Falklands	Crew, Gov staff, researchers, cargo	10-12	12 pax 10-12 crew
	Cruise ships	Falklands, South America, BAT	Passengers	68 vessels	8,780 pax total
	Yachts	Falklands, South America, BAT	Passengers	22 vessels	
	Royal Navy	Falklands, S Africa, S America, Antarctica	Military	4-6	

With regards current exotic animal and plant ownership, there are no zoos, pet shops or botanic gardens or garden centres importing exotic animals or plants.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on SGSSI
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	None
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	None
	Other mammals	None
	Fresh water fish	None
	Marine species	None

Existing non-native species

A total of 34 species met the parameters outlined in the methods section and were analysed, comprising 20 terrestrial invertebrate (17 insects, two arachnids and one annelid worm) and 14 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Diptera 8
- Thysanoptera 3
- Hemiptera 2
- Collembola 2
- Coleoptera 1
- Lepidoptera 1

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 34 as some species have several possible pathways of entry.

Table 5. Pathways of entry for 34 species at the category level

	Invertebrates	Plants	Overall
Release in nature	0	0	0
Escape from confinement	0	0	0
Transport – contaminant	12	0	12
Transport – stowaway	8	14	22
Corridor	0	0	0
Unaided	0	0	0

Table 6. Pathways of entry for 34 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0
	Hunting in the wild	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0
	Pet/aquarium/terrarium species (including live food for such species)	0	0
	Forestry (including afforestation or reforestation)	0	0
	Horticulture	0	0
	Ornamental purpose other than horticulture	0	0
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	0	0
	Food contaminant (including of live food)	9	0
	Contaminant on animals	0	0
	Parasites on animals (including species transported by host and vector)	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	0	0
	Seed contaminant	0	0
	Timber trade	0	0
	Transportation of habitat material (soil, vegetation)	3	0
TRANSPORT – STOWAWAY (4)	Container/bulk	0	13
	Hitchhikers on boat	5	0
	Hitchhikers on plane	0	0
	Machinery/equipment	4	14
	Organic packing material	0	0
	People and their luggage/equipment (in particular tourism)	0	2
	Vehicles (car, train, …)	0	0

For invertebrates, the commonest pathway of entry was via transport contaminant, primarily of food (mainly fresh produce). Three species, the drain fly *Psychoda parthenogenetica* and the two species of spider, are considered most likely to have been introduced as transport stowaways of machinery or equipment, and in the case of the drain fly, also possibly as a hitchhiker on boats. One species, the hoverfly *Eristalis croceimaculata* is considered most likely to have arrived via “an assisted passage aboard a visiting ship” (Key & Key, 2009), although it is possible that it arrived unaided, blown by wind. The lesser dung fly *Scatopse notata* and two species of blow fly *Calliphora vicina* and *Protophormia terraenovae* are also all considered most likely to have arrived as hitchhikers aboard ships; this is supported by the observation of a Calliphorid fly alighting the ship in the Falklands (Key & Key, 2009).

No non-native species of vertebrate have been introduced since 1980.

For plants, the commonest pathway of entry was considered introduction was transport stowaway, in most cases as general cargo or in machinery or equipment. Two species, brown bentgrass *Agrostis vinealis* and spike trisetum *Trisetum spicatum*, are noted in the literature as being transported on clothing and/or footwear and these pathways are also ticked.

Source of non-native species

For SGSSI there are relatively few possible points of entry both by land and sea, with direct access only from the Falkland Islands, and the UK via the Falklands. The possible source of non-native species in terms of their geographic distribution is shown in Table 7.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Plants
Americas only	1	3
UK/Europe only	5	1
Other combination	9	3
Widespread	5	7

The category “other combination” in all cases consisted of UK/Europe with North America, sometimes also included Australia. The UK/Europe is strongly implicated as the source of most non-native species.

Discussion

There is no permanent settlement in SGSSI and no agriculture, consequently all inferred pathways are unintentional, either as transport contaminants of food or as transport stowaways of equipment or personal baggage. Fresh produce and contaminated general cargo are the main commodities implicated here.

The majority of existing non-native invertebrates are flies (Insecta, Diptera), mainly small midges and gnats associated with fungus and detritus. Springtails (Collembola) are commonly intercepted from fresh produce and this is the inferred pathway for these two species as well as for the two species of aphid (Hemiptera) and *Aridius spathe*, the small scavenger beetle (Coleoptera).

All the non-native plant species are small annual weeds or grasses (Poaceae), typically producing quantities of small wind-blown seeds highly likely to be transported accidentally in mud or detritus, or attached to clothing and footwear.

It is possible that many of both the non-native plant and invertebrate species were actually introduced before 1980, one very likely pathway being the soil which Norwegians brought to place on their compatriots graves (Key & Key, 2009). However, as they weren’t recorded until more recently it has to be assumed that they may also have arrived later.

Most existing non-native species have a northern European or widespread distribution with European origin, a feature noted by Frenot et al (2005) of Antarctic invasions in general. Species enter the transport chain either in the UK or at port areas in South America or the Falklands where cosmopolitan non-native species are common.

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St Helena Island

Executive summary

- Points of entry to St Helena are relatively few, with direct routes from Europe and Africa, and indirect routes from the Americas via Ascension Island.
- Pathway analysis was done for 169 existing non-native species and for 31 recent interceptions.
- For invertebrates, the commonest pathway of entry was via transport, as a contaminant or as a stowaway.
- For plants, escape from confinement and as a transport contaminant are the commonest pathways of entry.
- For vertebrates, a single introduction occurred via shipping containers.
- Exotic pet and plant ownership is limited and this is not considered an important pathway.
- Most species have a current geographic distribution in areas which would allow them to enter the pathway of introduction directly via the single supply vessel, namely Europe and/or Africa.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Erosion control/ dune stabilization (windbreaks, etc)			*
	Landscape/flora/fauna “improvement” in the wild			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			*
	Forestry (including afforestation or reforestation)			*
	Horticulture			**
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	***		
	Food contaminant (including of live food)	***		
	Parasites on animals	**		
	Contaminant on plants	***		
	Seed contaminant	*		***
	Timber trade	*		
	Transportation of habitat material (soil, vegetation)	***		***
TRANSPORT – STOWAWAY (4)	Container/bulk	**	*	
	Hitchhikers in or on airplane	**		**
	Hitchhikers on ship/boat	*		
	Machinery/equipment	**		
	People and their luggage/equipment	*		*
	Organic packing material	**		
	Vehicles (car, train, …)	*		*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for St Helena.

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for St Helena by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for St Helena in 2014.

Taxon	Total species	Non-native species
Invertebrates	1,896	436
Vertebrates	213	13
Plants	823	339

The quality of baseline information in St Helena was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Good

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- Government of St Helena statistics office
- Biosecurity St Helena.

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	St Helena National Trust invertebrate database v5-3 May 2017	Up-to-date, database being actively populated under a Darwin Plus project
Plants	Flowering Plants and Ferns of St Helena (Lambdon 2012)	Does not cover common garden plants

Recent interceptions

Data was sourced from:

- Biosecurity St Helena unpublished database

Source of non-native species

For St Helena, each species' geographic distribution in UK/Europe, Africa, Americas, and Asia/Oceania was recorded.

Results

Points of entry

St Helena is a very isolated island, with few direct points of entry. The dedicated vessel RMS St Helena was until recently the only way into the island for both passengers and cargo; arrival takes five nights voyage from Cape Town, two nights voyage from Ascension Island, and 14 nights voyage from the UK. From 2012 to 2015 a second cargo vessel began operation, bringing in airport construction materials from Southern Africa. This is the first vessel to moor up in contact with the island, to a newly constructed wharf, as the RMS St Helena anchors one nautical mile in the bay and cargo is barged ashore. The airport officially opened in 2016.

Connectivity for 2016 is summarised in Table 3.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks in 2016.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	RMS St Helena	RSA, Ascension	Passengers, cargo	15 times RSA 17 times Asc	3,930 passengers, 1,023 shipping containers, 250 vehicles
	Fuel tanker	RSA	Fuel	6	Crew only, stop-over only
	Cruise ships	Within SA region: RSA, Namibia, TdC, Ascension	Passengers, crew	8	Typically, 250 – 2,500 passengers each; mostly day-trips
	Navy	Within SA region	Military crew	0 - 2	Typically 30 – 60 crew
	Yachts	RSA, Namibia	crew	186	Typically, 2 – 6 passengers each
	Other	Various	Oil rigs, miscellaneous vessels	varies	None in 2016
Air	Private jet	Various: Africa and S America	Passengers	18	6 to 20 passengers
	Medevac	RSA	Crew	3	Stop-over only
	Commercial	Europe via Africa	Passengers	None	None in 2016

Data from the Ships Register was analysed to determine the most common ports of origin for foreign vessels coming to St Helena (Biosecurity Protocol for the Marine Environment). From the 3rd January 2010 to the 3rd January 2015 of a total of 1184 calls of vessels to St Helena, 65.5% came from South Africa (including 55.3% from Cape Town and 4.0% from Simon's Town), 16.0% from Walvis Bay and 6.2% from Luderitz in Namibia, and 7.8% from Ascension Island. The remainder came from other various ports. The RMS St Helena made up 11.4% of these 1184 calls.

With regards current exotic animal and plant collections, St Helena has no zoos or public aquaria, and one historic botanic garden dating from the late 1700s which is no longer maintained as such; see Table 4. There are strict regulations on the importation of live animals and plants.

Table 4. Exotic animal and plant collections and ownership

Type	Detail	Presence on St Helena
Zoos		None
Botanic gardens		Historic and not maintained
Public aquaria		None
Pet ownership:	Parrots	None
	Other birds	None
	Reptiles	4 Aldabra giant tortoises
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits, guinea pigs
	Other mammals	None
	Fresh water fish	Goldfish *Carassius auratus*, koi carp *Cyprinus carpio*, suckermouth catfish *Hypostomus plecostomus,* Guppy *Poecilia reticulata*
	Marine species	None

Existing non-native species

A total of 169 species met the parameters outlined in the methods section and were analysed, comprising 120 terrestrial invertebrates (102 insects, 11 arachnids, five molluscs, one isopod and one nematode) and 49 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hymenoptera 31
- Hemiptera 17
- Coleoptera 14
- Lepidoptera 13
- Diptera 12
- Psocoptera 7
- Collembola 6
- Mantidae 1
- Thysanoptera 1

The number of species considered to have been introduced via pathways of entry at the category level are given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 169 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport as a contaminant, primarily of live plants and nursery material, followed by fresh produce and transport of habitat material. Species listed as parasites on animals are Hymenopteran parasitoids and hyperparasitoids which are considered most likely to have come in via the infected host.

Transport as stowaways is the second commonest pathway of entry, with shipping containers and organic packing material considered the most vulnerable commodities to carry stowaways. Twelve species could have arrived via two pathways at the category level, transport contaminant or stowaway; tramp ant species are typical of this group. A total of 11 species are recorded as intentional introductions into the wild as biocontrol agents.

No new vertebrate species have been introduced since 1980.

For plants, escape from confinement and transport contaminant are the commonest pathways of entry. The main escape was considered to have been introduced as an ornamental, and the main contaminant is of small, annual weedy species as seed contaminants. Four species could have arrived via two pathways at the category level, three either as escapes from confinement or transport contaminants, and one either transport contaminant or stowaway.

Table 5. Pathways of entry for 169 species at the category level

	Invertebrates	**Plants**	**Overall**
Release in nature	11	2	13
Escape from confinement	0	26	26
Transport – contaminant	94	25	119
Transport – stowaway	27	1	28

Table 6. Pathways of entry for 169 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Biological control	11	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	1
	Landscape/flora/fauna "improvement" in the wild	0	1
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	4
	Forestry (including afforestation or reforestation)	0	4
	Horticulture	0	16
	Ornamental purpose other than horticulture	0	1
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	38	1
	Food contaminant (including of live food)	31	0
	Parasites on animals (including species transported by host and vector)	15	0
	Contaminant on plants (except parasites, species transported by host/vector)	40	0
	Seed contaminant	5	25
	Timber trade	6	0
	Transportation of habitat material (soil, vegetation)	35	21
TRANSPORT – STOWAWAY (4)	Container/bulk	18	0
	Hitchhikers on ship/boat (excluding ballast water and hull fouling)	4	0
	Machinery/equipment	11	1
	People and their luggage/equipment (in particular tourism)	4	1
	Organic packing material, in particular wood packaging	15	0
	Vehicles (car, train, …)	6	1

Recent interceptions

A total of 31 species were intercepted between 2014 and 2016, comprising 29 terrestrial invertebrate, 1 reptile and 1 plant species. Only two pathways categories were identified, transport contaminant and transport stowaway. The number of species considered to have been introduced via pathways of entry at the category level are given in Table 7, and subcategory level in Table 8. Note numbers add to more than 31 as some species have been intercepted more than once.

The reptile was an Afro-American house gecko *Hemidactylus mabouia* intercepted in a shipping container from Ascension Island. The plant was an ice-plant species *Galenia papulosa (*Aizoaceae), which germinated from river sand imported as part of the airport construction project. The majority of invertebrates were intercepted on fresh produce; Tephritid fruit fly larvae on imported stone fruit are common. The high numbers intercepted in shipping containers and vehicles refer mainly to spiders.

Table 7. Pathways of entry for 31 intercepted species at the category level

	Invertebrates	Plant	Reptile
Transport – contaminant	14	1	
Transport – stowaway	15		1

Table 8. Pathways of entry for 31 intercepted species at the sub-category level

Category	Sub-category	Invertebrates	Plant	Reptile
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	3		
	Food contaminant (including of live food)	14		
	Contaminant on plants (except parasites, species transported by host/vector)	3		
	Transportation of habitat material (soil, vegetation)		1	
TRANSPORT - STOWAWAY (4)	Container/bulk	8		1
	Machinery/equipment	1		
	Vehicles (car, train, …)	9		

Source of non-native species

For St Helena, possible points of entry are directly from Europe and Africa, or from the Americas via Ascension. The possible source of non-native species is shown in Table 9, for both existing species and recent interceptions, in terms of their geographic distribution. Distribution data was not found for four invertebrate species.

Table 9. Geographic distribution of non-native species

Possible source	Invertebrates - existing species	Invertebrates - recent interceptions	Plants - existing species
Europe (not Africa or Americas)	15	6	3
Africa (not Europe or Americas)	21	10	1
Americas (not Europe or Africa)	5	0	4
Europe and Africa (not Americas)	1	2	1
Europe and Americas (not Africa)	23	7	4
Africa and Americas (not Europe)	8	1	7
Asia/Oceania only	5	0	3
Widespread	27	4	26

Most invertebrates have a current distribution in areas with direct access to the island, namely Europe and/or Africa, followed by the Europe + Americas possible route. No species

occur which are only known from the Americas, however five species are only known from Asia/Oceania with no direct pathway to the island.

The majority of plant species have a widespread geographic distribution. Note that for plant species, geographic distribution is less informative as most introductions ae intentional.

Discussion

Live plants and associated material stand out as a historic source of non-native species, particularly invertebrates. This pathway is now regulated with a licence system is in place, requiring pre-border checks and treatments which act as a disincentive to bring in new ornamental plants. However, capacity on-island to carry out a risk assessment of new species is poor. It is still possible to import commercially sourced plant seeds with no controls and this is potentially a source of new invasive plant species. A Darwin Plus project on weed management starting in 2017 includes the development of black lists of plant species and public awareness on invasive plant risks will address this.

A relatively high proportion of recent interceptions were made from shipping containers and vehicles. These had not been subject to routine biosecurity inspection prior to 2014 and clearly provide a source of hitchhiker species such as spiders not previously realised. This pathway is now being addressed with the development of inspection protocols and greater manpower to carry out routine inspections.

Eleven biocontrol agents were introduced in 1990s and early 2000s, all host-specific parasitic wasps or ladybirds, and their introduction followed FAO guidelines which evolved into International Standard Phytosanitary Measure No. 3. No adverse effects have been observed from any of the intentionally introduced species, which have been mostly successful as biocontrol agents.

The supply vessel, RMS St Helena, was inferred as the pathway for two species of stowaways, the harlequin ladybird *Harmonia axyridis* and white fruit chafer *Mausoleopsis amabilis*. The ship is known to have brought in adult large white butterflies *Pieris rapae* as stowaways at least three times in the past. For *Harmonia*, there was reports of observations of ladybirds on the ship a few weeks before first sighting on island. The importance of the air pathway with regards stowaways is unknown.

Examination of the possible origin of non-native species as evidenced by geographic distribution suggests that the majority come by the direct pathway routes from Europe and Africa. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

Exotic pet ownership very low and this is not considered an important pathway for St Helena.

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Tristan da Cunha

Executive summary

- Points of entry to Tristan da Cunha are relatively few, with direct access only from South Africa and the UK.
- Pathway analysis was done for 154 existing non-native species that were first recorded since 1980.
- For invertebrates, the commonest pathway of entry was as transport contaminant of habitat material (eg compost, aggregate, etc.), followed by live plants.
- No new species of non-native vertebrate were introduced since 1980, although a live gecko was intercepted.
- Exotic pet ownership is not considered an important pathway for Tristan da Cunha.
- The main pathways of introduction for plants was escape from confinement, mainly following introduction for horticulture as garden plants.
- Most introduced species are not confined to the region and have a widespread geographic distribution.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Plants
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)		*
	Forestry		*
	Horticulture		***
	Ornamental purpose		*
TRANSPORT – **CONTAMINANT (3)**	Contaminant nursery material	**	*
	Food contaminant (including of live food)	**	
	Parasites on animals	*	
	Contaminant on plants	***	
	Seed contaminant		*
	Timber trade	*	
	Transportation of habitat material	***	**
TRANSPORT – **STOWAWAY (4)**	Container/bulk	**	
	Hitchhikers on boat	*	
	Machinery/equipment	*	*
	Organic packing material	*	
	People and their luggage/equipment	*	*
	Vehicles (car, train, …)	*	*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the separate document “Pathway analysis – methods”.

This report presents the results of the pathway analysis for Tristan da Cunha Islands (“Tristan”).

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for Tristan by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for Tristan da Cunha in 2014.

Taxon	Total species	Non-native species
Invertebrates	880	126
Vertebrates	199	4
Plants	826	150

The quality of baseline information in Tristan was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Good	Basic

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- https://www.cruisetimetables.com/cruises-to-tristan-da-cunha.html
- www.tristandc.com/shipping.php
- http://www.tristandc.com/cruises.php

Visitor statistics are sourced from:

- Tristan Government Tourism Department

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Hänel & Pont (2008).	Checklist of house flies
	Horstmann 2008	Checklist of Ichneumon flies
	Gaston et al (2002)	Checklist of invertebrates on Gough Island
Plants	McIntosh & Malan (2012)	Plant inventory, survey did not include gardens
	Gremmen & Halbertsma (2009)	Alien plant report, covers gardens
	Anon (2015a)	Plant inventory for Gough Island
	Anon (2015b)	Plant inventory for Inaccessible Island

Results

Points of entry

There is no airport on Tristan da Cunha and access is entirely by sea. Up to 2016, the mail ship RMS St Helena visited Tristan da Cunha annually or biannually, bringing passengers and a small amount of cargo. The last voyage will take place in January 2018.

Two fishing vessels, the MV Geo Searcher and MV Edinburgh, service the islands, visiting from Cape Town in South Africa up to nine times a year bringing passengers and cargo to Tristan Main Island. In addition, the South African research vessel, the SA Agulhas II visits once a year to service the weather station on Gough Island, dropping off passengers and cargo to Tristan main island; it can carry up to 100 passengers in 46 cabins and has a 4,000 m^3 (140,000 cu ft) cargo hold.

Local boats go from the main island to Nightingale and Inaccessible Islands up to a dozen times a year, during the summer season.

Connectivity is summarised in Table 3 for 2016.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks.

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Vessels	MV Edinburgh	Cape Town	Passengers, cargo	9	
	MV Baltic Trader	Cape Town	Passengers, cargo	9	
	SA Agulhas II	Cape Town	Passengers, some cargo	Annual	Up to 100 pax
	Cruise ships	Varied	Passengers	Up to 6	387 pax total
	Yachts	China, Argentina, Montevideo, South Africa, France	Crew	6	35 pax

In 2016, a total of five cruise ships with 387 passengers and six yachts with 35 crew visited Tristan da Cunha.

With regards current exotic animal and plant ownership, there are no zoos, pet shops or botanic gardens or garden centres importing exotic animals or plants. Importation of domestic pets (dogs only are allowed) is regulated.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on Tristan
Zoos		None
Botanic gardens		None
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	None
	Reptiles	None
	Other	None
	Amphibians	None
	Domestic cats, dogs, small mammals	Dogs
	Other mammals	None
	Fresh water fish	Gold fish, koi carp (TBC)
	Marine species	None

<u>Existing non-native species</u>

A total of 154 species met the parameters outlined in the methods section and were analysed, comprising 91 terrestrial invertebrate (75 insects, five arachnids, five molluscs, three myriapods, two annelid worms and one crustacean, a woodlouse) and 63 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Diptera 17
- Hemiptera 14

- Coleoptera 14
- Collembola 7
- Hymenoptera 6
- Thysanoptera 6
- Lepidoptera 4
- Psocoptera 4
- Orthoptera 1
- Thysanura 2

The number of species considered to have been introduced via pathways of entry at the category level is given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 154 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly of habitat material (eg compost, aggregate, etc.), followed by live plants, and then nursery material (soil) and food (mainly fresh produce). The second commonest pathway of entry was as transport stowaway, mainly in shipping containers, which included most of the species of spider, cockroach, silverfish, woodlouse, a wood borer and some species of psocoptera. Five species could have arrived via two pathways at the category level, transport contaminant or stowaway, namely a spider, centipede, wood borer, psocoptera and the woodlouse.

No non-native species of vertebrate have been introduced since 1980 (but see interceptions, below).

For plants, the commonest pathway of entry was introduction was escape from confinement, mainly following introduction for horticulture as garden plants or, less commonly, introduction for agriculture. Less common was introduction as transport contaminant, primarily of habitat material followed by contaminant of seed. The habitat material implicated included aggregate and composts, etc.

Table 5. Pathways of entry for 154 species at the category level

	Invertebrates	Plants	Overall
Release in nature	0	0	0
Escape from confinement	0	42	42
Transport – contaminant	82	18	100
Transport – stowaway	14	2	16
Corridor	0	0	0
Unaided	0	0	0

Table 6. Pathways of entry for 154 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0
	Hunting in the wild	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	7
	Pet/aquarium/terrarium species (including live food for such species)	0	0
	Forestry (including afforestation or reforestation)	0	2
	Horticulture	0	31
	Ornamental purpose other than horticulture	0	2
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	13	3
	Food contaminant (including of live food)	13	0
	Contaminant on animals	0	0
	Parasites on animals (including species transported by host and vector)	6	0
	Contaminant on plants (except parasites, species transported by host/vector)	31	0
	Seed contaminant	0	6
	Timber trade	3	0
	Transportation of habitat material (soil, vegetation)	36	14
TRANSPORT – STOWAWAY (4)	Container/bulk	12	0
	Hitchhikers on boat	4	0
	Hitchhikers on plane	0	0
	Machinery/equipment	1	1
	Organic packing material	2	0
	People and their luggage/equipment (in particular tourism)	2	1
	Vehicles (car, train, …)	3	1

Recent interceptions

Some interception data is available. At least three non-native species seedlings were found growing amongst sand imported from South Africa for construction purposes (McIntosh & Malan, 2012). In 2010 larvae of longhorn beetles (Cerambycidae) were found in timber packaging imported from South Africa for a construction project (Reid & Malumphy, 2010). A live sparrow arrived a few years ago, a bird's nest in the housing of some machinery, and more recently there was a live gecko and live cabbage white butterfly *Pieris* spp. (K. Herian, pers. comm.).

Source of non-native species

For Tristan da Cunha there are relatively few possible points of entry both by land and sea, with direct access only from South Africa, and the UK via South Africa. The possible source of non-native species in terms of their geographic distribution is shown in Table 7.

Table 7. Geographic distribution of non-native species.

Possible source	Invertebrates	Plants
UK/Europe only	6	0
UK/Europe + Africa	4	3
UK/Europe + Americas	14	1
UK/Europe + other (not Africa or Americas)	5	0
Americas only	2	0
Africa only	5	1
Asia only	1	1
Other combination	5	6
Widespread	42	54

The majority of all existing non-native species of all taxa have a widespread geographic distribution, suggesting local trade is not important as the main ultimate pathway of introduction. Invertebrates tend to have a geographic distribution which includes UK/Europe rather than Africa. Note that for plant species, geographic distribution is less informative as a large proportion of introductions are intentional.

Discussion

Agriculture is important for Tristan as people rely heavily on the annual potato crop and livestock (cattle and sheep). There is also a limited amount of salad crops grown in greenhouses.

The commonest inferred pathway for existing non-native invertebrate species was mostly as a transport contaminant of habitat material and of live plants.

The main pathway of introduction implicated for plants is escape from confinement following introduction for horticulture, and this pathway clearly requires regulation. Transport contamination of habitat material (aggregate, composts, etc) is also important although less so. There is no information on interceptions from routinely imported fresh produce and personal cargo, but the limited data available on interceptions suggests that transport stowaway is potentially a high risk pathway for both plants and invertebrates.

Internal biosecurity is of concern for Tristan. The permanent population live on the main island, and there is a manned weather station on Gough Island where around seven people live for 1-year periods, being replaced annually. Nightingale and Inaccessible Islands are visited regularly by Tristanians, researchers and, in the case of Nightingale, tourists. Biosecurity protocols have been drafted for Nightingale Island, but not Inaccessible; biosecurity controls are much stricter for Gough Island which is a World Heritage Site and for

which a mouse eradication programme is in the planning stages. Only one non-native plant species is noted only to occur on Gough Island, *Lolium multiflorum* Italian ryegrass, while two were noted only to occur on Inaccessible: *Pinus caribea* Caribbean pine and *Pseudognaphalium luteoalbum* Jersey cudweed.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread. Gaston et al (2002) found that 83% of the non-native insect species on Gough Island are either Holarctic in origin or with widespread Holarctic distributions, considering that the majority of these species are likely to have arrived via shipping from European ports or from Southern Africa where introduced populations of many of these species occur in the Cape Town region. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and researchers.

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Turks and Caicos Islands

Executive summary

- TCI has direct access from a number of other countries outside and within the Caribbean region, both by air and sea.
- Pathway analysis was done for 163 existing non-native species, and for 35 recent interceptions from fresh produce.
- For invertebrates, the commonest pathway of entry was via transport as a contaminant.
- For vertebrates, intentional introduction, transport contaminant and transport stowaway were equally important; the exotic pet trade is potentially considered an important pathway.
- Hurricanes are a known factor in the arrival and spread of vertebrate species.
- For plants, escape from confinement was the commonest pathway of entry.
- Most introduced species are not confined to the region and have a widespread geographic distribution, suggesting that global trade is more important than local trade.

Summary of pathways for horizon scanning, with number of asterisks increasing with importance of the pathway (yellow =*, orange = ** and red = ***).

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Erosion control/ dune stabilization			*
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)			***
	Pet/aquarium/terrarium species		*	
	Forestry			*
	Horticulture			***
	Ornamental purpose			*
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	*		**
	Food contaminant (including of live food)	*		
	Contaminant on plants	*	*	
	Seed contaminant			***
	Timber trade	*		
	Transportation of habitat material	*		**
TRANSPORT – STOWAWAY (4)	Container/bulk	*		
	Hitchhikers on boat	*	*	
	Hitchhikers on plane	*		
	Machinery/equipment	*		*
	Organic packing material	*		
	People and their luggage/equipment	*		*
	Vehicles (car, train, …)			*

Introduction and methods

Standard methods have been used for the pathway analysis in each OT and are given in the general methods section.

This report presents the results of the pathway analysis for the Turks and Caicos Islands (TCI).

Baseline

An overview of numbers of total number of non-native species (marine and terrestrial) recorded for TCI by the RSPB Stocktake is summarised in Table 1 (Churchyard et al 2014).

Table 1. Summary of species numbers for TCI in 2014.

Taxon	Total species	Non-native species
Invertebrates	480	9
Vertebrates	560	16
Plants	809	111

The quality of baseline information in TCI was assessed for terrestrial plants and animals (vertebrate and invertebrate), as shown below:

Plants	Animals
Basic	Basic

Sources of information

Points of entry

Information for connectivity and exotic animal and plant ownership were sourced from:

- http://caribya.com/
- http://www.cruisetimetables.com/
- http://www.zoos-worldwide.de/index.php/caribbean/127-places-to-visit/caribbean/
- http://turksandcaicostourism.com/

Visitor statistics are sourced from:

- Central Statistics Office, Government of Turks and Caicos Islands

Existing non-native species

A checklist of existing non-native species was put together from the sources in Table 2.

Table 2. Sources of data

Taxonomic group	Source	Status of the data
Invertebrates	RSPB database used for stocktake (Churchyard et al 2014)	Comprehensive from published data sources, up to date in 2014
	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
Plants	CABI Invasive Species Compendium	Variable in terms of coverage and how up to date
	Broome, R, Sabir, K, Carrington, S. (2007) "Plants of the Eastern Caribbean" http://ecflora.cavehill.uwi.edu/index.html	Comprehensive, up to date in 2007
	Acevedo-Rodríguez, P. & M.T. Strong. (2007) Catalogue of the seed plants of the West Indies http://botany.si.edu/Antilles/Westindies/	Comprehensive, up to date in 2007

Recent interceptions

Interception data from inspected fresh produce (fruit and vegetables) is available for the first seven months of 2017.

Data was sourced from Ms Wilhelmina Kissoonsingh, Director**,** Department of Agriculture.

Results

Points of entry

TCI currently has two full service international airports, the main one on Providenciales, and a smaller one on Grand Turk servicing mainly domestic flights and charter flights. All other inhabited islands have domestic airports, some with limited international entry. There are direct daily flights from the USA and Canada as well as daily direct flights from within the region, including Antigua, Bahamas, Dominican Republic, Haiti and Jamaica. Some islands, such as Ambergris Cay have long runways capable of receiving private jets, but there is no data on the frequency or origin of flights and no checks are made.

There is a cruise ship terminal in Grand Turk, and at least seven marinas for yachts and private boaters. In addition, there are a number of private docks at larger houses where boats can arrive unchecked, and for which there is no data. It is known that small fishing boats arrive from Haiti carrying produce, live chickens and other commodities which land outside official ports of entry on beaches.

Cargo ships bring fresh produce, containerised goods and break-bulk cargo, mainly from the USA. Cargo includes topsoil, construction materials, and used vehicles, including used garbage trucks from the USA. The TCI imports nearly all goods via its marine ports and South Dock Providenciales receives more than 85% of such imports. During 2016/17; 15,291 containers, 23,258 tons of cargo and 2,127 vehicles were imported through South Dock. In the same year there was approximately 400 international ship visits and about 126 inter-island ships voyages.

Local ferries move between Providenciales and North and South Caicos with numerous sailings each day; there are no international ferry services. There is also a private ferry

connecting Grand Turk and Salt Cay. Passenger numbers are increasing each year, having risen from 33,500 for 2014/2015 to 39,875 for 2016/2017 for North Caicos arrivals and from 2,237 to 2,490 for South Caicos arrivals in the same time periods.

Connectivity is summarised in Table 3 for 2015.

Table 3. Key pathways and volumes that carry potential terrestrial biosecurity risks

	Carrier	Point of origin	Description	Frequency per annum	Stats/trip
Sea	Cruise ship	Various	Passengers and crew	317	929,737 arrivals
	Ferry	TCI	Local services only, within TCI	Numerous daily sailings	2016/2017 data - North Caicos: 39,875 pax South Caicos: 2,490 pax
	Yacht	Various	Crew		Around 1,190 arrivals
	Cargo ship		Crew		No information
	Fuel tanker		Crew		No information
	Military vessels		Crew	Yearly visit	
	Misc				No information
Air	Private jet		Passengers and crew		8,206 arrivals
	Commercial	USA (direct flights from eg Chicago, Florida) and Canada. Regional flights from Antigua, Dominican Republic, Jamaica and Bahamas	Passengers	Several flights a day	385,531 arrivals
	Medevac				No information

In 2015, a total of 1,315,268 visitors arrived in TCI, of which 385,531 were stop-over arrivals, and 929,737 were cruise ship passengers. The majority of stop-over arrivals came from North America (82% from the United States and 9.5% from Canada). A total of 16,889 stop-over arrivals (4.4% of the total) came from the Caribbean region.

With regards current exotic animal and plant ownership, TCI has no zoos or public aquaria and there are two botanic gardens which promote local species. There is one plant nursery, a number of private landscaping companies and resorts which import exotic ornamental plants, primarily from the USA. There are no pet shops, although some people breed pet species for sale locally. Table 4 shows the status of exotic animal and plant presence and ownership.

Table 4. Exotic animal and plant presence and ownership

Type	Detail	Presence on TCI
Zoos		None
Botanic gardens		Two, now promoting local species
Public aquaria	None	None
Pet ownership:	Parrots and cage birds	Parakeets, Lady Gouldian finches
	Reptiles	Green iguanas, savanna monitor lizard, red-eared slider
	Amphibians	None
	Domestic cats, dogs, small mammals	Cats, dogs, rabbits, guinea pigs, ferrets
	Other mammals	none
	Fresh water fish	*Betta splendens* (tanks), goldfish and koi carp (ponds)
	Marine species	None

Existing non-native species

A total of 163 species met the parameters outlined in the methods section and were analysed, comprising 11 terrestrial invertebrate (all insects), 9 terrestrial vertebrate (six reptiles, two birds and one amphibian), and 143 terrestrial plant species. Taxonomic breakdown of insects is as follows:

- Hemiptera 3
- Hymenoptera 3 (all ant species)
- Isoptera 3
- Lepidoptera 1
- Diptera 1

The number of species considered to have been introduced via pathways of entry at the category level are given in Table 5, and subcategory level in Table 6. Three risk levels have been arbitrarily defined: lowest risk 1 to 10, medium risk 11 to 20, and highest risk 21 and above. Note numbers add to more than 163 as some species have several possible pathways of entry.

For invertebrates, the commonest pathway of entry was via transport contaminant, mainly on live plants, timber and transport of nursery material (principally related to the presence of soil). Three species could have arrived via two pathways at the category level, transport contaminant or stowaway, all ant species.

For vertebrates, the commonest pathways of entry are escape from confinement, having been introduced as pets (Cuban tree frog, green iguana, red eared slider and ring neck dove) and transport contaminants of live plants (chameleon, agamid lizard and northern curly-tailed lizard). The corn snake also probably arrived as a transport contaminant of live plants although this is unconfirmed; see below under recent interceptions.

For plants, the commonest pathway of entry was escape from confinement, mainly following introduction for horticulture or, less commonly, introduction for agriculture. The second commonest pathway of entry was via transport contaminant, primarily of seed and nursery

and habitat material; these species are mainly small annual weeds, together with *Cyperus* nut-sedges. Eight species could have arrived via two pathways at the category level, four as transport contaminant or stowaway, three as escapes from confinement or release into nature, and one species as escape from confinement or transport contaminant.

Table 5. Pathways of entry for 163 species at the category level

	Invertebrates	Vertebrates	Plants	Overall
Release in nature	0	0	2	2
Escape from confinement	0	4	108	112
Transport – contaminant	10	4	35	49
Transport – stowaway	4	2	5	11

Table 6. Pathways of entry for 163 species at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

Category	Sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	0	0	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	2
	Landscape/flora/fauna "improvement" in the wild	0	0	0
	Medical use	0	0	0
	Release in nature for use (other than above, e.g., fur, transport, medical use)	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	0	0	31
	Pet/aquarium/terrarium species (including live food for such species)	0	4	0
	Forestry (including afforestation or reforestation)	0	0	5
	Horticulture			62
	Ornamental purpose other than horticulture	0	0	10
TRANSPORT – CONTAMINANT (3)	Contaminant nursery material	3		15
	Food contaminant (including of live food)	1	0	0
	Parasites on animals (including species transported by host and vector)	0	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	8	4	0
	Parasites on plants (including species transported by host and vector)	0	0	0
	Seed contaminant	0	0	24
	Timber trade	5	0	0
	Transportation of habitat material (soil, vegetation)	2	0	17
TRANSPORT – STOWAWAY (4)	Container/bulk	2	0	0
	Hitchhikers on boat	2	2	0
	Hitchhikers on plane	1	0	0
	Machinery/equipment	0	0	4
	Organic packing material	1	0	0
	People and their luggage/equipment (in particular tourism)	3	0	4
	Vehicles (car, train, …)	0	0	5

Recent interceptions

A total of 36 interceptions of 85 individual specimens have been intercepted in 2017. Specimens have only been identified at the higher taxonomic level and are as follows:

- Hemiptera: 9 interceptions of a total of 26 individuals (23 of which are mealybugs)
- Lepidoptera: 7 interceptions of a total of 12 caterpillars
- Hymenoptera: 3 interceptions of a total of 3 wasps
- Coleoptera: 2 interceptions of a total of 2 individuals
- Centipedes: 2 interceptions of a total of 2 individuals

- Unspecified insect larvae (Diptera, Lepidoptera): 12 interceptions of a total of 32 larvae
- Molluscs: 2 interceptions of a total of 10 individuals (9 slugs, 1 snail)

Interceptions were made from a total of 15 different types of produce; see Table 7 for details.

Table 7. Numbers of interceptions and specimens intercepted from fresh produce in 2017.

Produce	No. interceptions	No. specimens	Taxonomic groups of interceptions
Soursop (*Annona muricata*)	7	24	Hemiptera (mealybugs), Hymenoptera, unspecified larvae
Calaloo (*Amaranthus cruentus* sp.)	7	11	Coleoptera, Lepidoptera, unspecified larvae, centipede
Christophine (*Sechium edule*)	3	9	Lepidoptera; unspecified larvae
Corn on the cob	3	5	Lepidoptera
Okra	3	3	Lepidoptera, Hemiptera (stink bug), Hymenoptera
Mango	2	11	unspecified larvae
Hot peppers	2	2	Hemiptera, unspecified larvae
Pineapple	2	2	Coleoptera, Hemiptera
Yam	2	2	unspecified larvae, centipede
Cabbage	1	9	Slugs
Guava	1	3	unspecified larvae
Beans	1	1	unspecified larvae
Parsley	1	1	Snail
Thyme	1	1	Hymenoptera
Plantain	1	1	Hemiptera (mealybug)

In addition, the Department of Environment and Coastal Resources (DECR) reports the following interceptions:

- Corn snakes reached Grand Turk probably with large import consignments (unconfirmed) of large trees for the Cruise Terminal
- Cuban knight anoles also probably with large import consignments (unconfirmed) of large trees to Beaches and Amanyara
- Marine toads and African land snails most likely came from Haiti
- Parrots smuggled from Haiti in 2012: juvenile cockatiels, African peach-faced lovebirds, and Hispaniolan parrots
- Earthworms in soil with pot plants from the USA

Source of non-native species

For TCI, there are several possible points of entry both by land and sea, with direct access from a number of other countries within the Caribbean region as well as the USA and Canada. The possible source of non-native species is shown in Table 8 for existing species in terms of their geographic distribution, where data was available. All the interceptions were made from produce originating within the region, 35 from produce originating in Haiti and one (of nine slugs on cabbage) from the Dominican Republic.

Table 8. Geographic distribution of non-native species.

Possible source	Invertebrates	Vertebrates	Plants
Wider Caribbean	0	0	6
Wider Caribbean plus Americas	1	3	15
Americas (not wider Caribbean)	1	0	0
Europe only	0	0	2
Africa only	0	0	1
Asia/Oceania only	0	0	2
Other combination	0	3	10
Widespread	7	3	103

The majority of all existing non-native species of all taxa have a widespread geographic distribution. A small number of invertebrate species are known from the wider Caribbean region plus mainland Americas. Note that for plant species, geographic distribution is less informative as most introductions are intentional. Also, two of the vertebrate species have not been identified to species (chameleon, agamid lizard) and are recorded as “other” distribution as it is not possible to be more exact.

Discussion

The majority of terrestrial invertebrates are considered most likely to have been introduced as transport contaminants, mainly of live plants and associated soil (nursery material and habitat material). The recent interception data also clearly demonstrates the importance of fresh produce as a pathway of introduction for a range of invertebrate species. However, the database is very weak for non-native invertebrates, with a total of 11 terrestrial species meeting the parameters for analysis. All 11 species are insects but beyond this no one group dominates taxonomically, and five Orders are represented: Diptera, Hemiptera, Hymenoptera, Isoptera and Lepidoptera. Species identifications are lacking for recent interceptions so the extent of overlap with the list of existing non-native species is not known, but one additional insect Order, Coleoptera, is represented as well as centipedes. Results for invertebrates should be considered inconclusive in view of the low numbers.

Deliberate introduction is the main pathway of entry of plant species, which then escape from gardens or agricultural areas. Introduction as seed and nursery and habitat material contaminant was also important.

The pet trade is the probable source of four of the vertebrate species, two reptiles, a frog and a bird (ring neck dove). Exotic pet ownership is of concern; although there is no pet shop in TCI, in 2012 a number of smuggled parrots were intercepted suggesting a certain level of interest in exotic pets. Imports of exotic animals and birds are now tightly regulated. For sparrows, there are a few on North Caicos (probably on Providenciales too, but recently not observed) which arrived most likely by cargo ships to Grand Turk and South Caicos in the 1990s or 2000s and later arrived on North Caicos after a hurricane in 2009. Other exotic birds have made it to TCI through hurricane activity. In 2004 a flock of 30 tricoloured munia (*Lonchura malacca*) was seen on North Caicos (this species is established as escaped cage birds in Puerto Rico and Hispaniola) but they didn't survive. Occasional regional vagrants also arrive through storm activity. Hurricanes and storms will almost certainly also bring plant

and invertebrate propagules but these have so far gone unrecorded or have failed to establish.

Of particular concern is the importation of large quantities of top soil for landscaping, soil being a high-risk commodity. Also, there are two horse riding businesses in Turks and Caicos who import habitat material in the form of hay and straw, as well as feed. A large piggery also imports animal feed.

Examination of the possible origin of non-native species as evidenced by geographic distribution found that the majority of species are widespread and no particular routes are implicated, suggesting global trade is more important than local trade within the Caribbean region (including the rim countries) as the main ultimate pathway of introduction. Note that species could potentially come from anywhere indirectly via trade links, expatriate workers and tourism.

Caveat

This analysis was done in 2017 prior to the impact of hurricanes Irma and Maria. Pathways may have changed post-hurricane.

References

Churchyard, T., Eaton, M., Hall, J., Millett, J., Farr, A., Cuthbert, R. and Stringer, C. (2014). The UK's wildlife overseas: a stocktake of nature in our Overseas Territories. Sandy, UK: RSPB.

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General Results and Discussion

Overall, a total of 2,629 introductions of existing non-native species were analysed across 15 Territories. This number is not equivalent to the total number of species as a number of species are common across several OTs. Of the 2629, the greatest number of introductions were of plants at 1,515 (58%), then invertebrates at 1030 (39%) and finally vertebrates at 84 (3%). This may reflect a real preponderance of plant species or simply the relative strength of available databases. Only eight of the 15 OTs included in this pathway analysis have databases scored as "Good" for both plants and animals (defined in this case as vertebrates and invertebrates). Data on plants tends to be better, with 12 Territories scoring "Good", one "Some" and two "Basic", while for animals only eight had databases scoring "Good", with two scoring "Some", four "Basic" and one, Pitcairn, scoring "None". Where there are few species listed, the totals for the various pathways will also be low and it is not possible to distinguish where this is an artefact of a weak database and where it is a real reflection of a less important pathway. For example, the territories of BAT and SGSSI have totals of 5 and 17 non-native invertebrate species respectively which meet the criteria for inclusion in the database, the animal database for both is scored is as "Good" and as these are well researched Territories there is a high level of confidence that all non-native species have been captured. On the other hand, the Territories of Pitcairn and TCI have comparative totals of 5 and 11 non-native insect species respectively, but as their animal databases are scored as "None" and "Basic" respectively these figures are expected to under-represent actual number of introduced non-native invertebrates in both cases. Spiders tend to be particularly poorly represented in the national databases, as well as the smaller and more obscure invertebrate fauna such as barkflies, webspinners, thrips, springtails, nematodes and such like.

It is important to note that the groupings used of "plant", "invertebrate" and "vertebrate" are very broad. "Plants" includes angiosperms and gymnosperms, with no non-native lichens, fungi, mosses or liverworts being recorded in the databases. "Vertebrate" is a very disparate group with the commonest introductions being of reptiles (46 introductions, 55%) followed by birds (28 introductions, 33%), while introductions of amphibians (7 introductions, 8%) and mammals (3 introductions, 4%) are relatively uncommon. The "invertebrate" group is even more diverse, covering as it does a range of taxa from the most commonly introduced insects with 823 (80%) introductions recorded, followed by 139 of arachnids (13.5%), 26 of molluscs (2.5%), 20 of annelids (2%), 12 of myriapods (1%), 4 of planarians/nemerteans (0.4%), 3 of nematodes (0.3%) and finally crustaceans (woodlice) with only three introductions recorded (0.3%), in each case of a single species of woodlouse.

Despite this variation, the groupings broadly share commonalities and some general conclusions can be drawn. Table 1 shows the inferred pathways for existing non-native species at category level and Table 2 at subcategory level; categorisation of pathways is taken from the Convention on Biological Diversity SBSTTA 18 and definitions are given in the methods section. Note that numbers exceed 2,629 as some species were scored in more than one category or subcategory when the most likely pathway of entry was unclear.

Table 1. Inferred pathways of entry for existing non-native species in 15 OTs at the category level.

	Invertebrates	Vertebrates	Plants	Overall
INTENTIONAL INTRODUCTIONS				
Release in nature	26	5	12	43
Escape from confinement	4	48	1101	1153
TOTAL INTENTIONAL	30	53	1113	1196
UNINTENTIONAL INTRODUCTIONS				
Transport – contaminant	827	18	387	1232
Transport – stowaway	251	16	66	333
TOTAL UNINTENTIONAL	1078	34	453	1565
OTHER INTRODUCTIONS				
Corridor	0	0	2	2
Unaided	4	4	5	13
TOTAL OTHER	4	4	7	15
TOTAL INTRODUCTIONS	1102	91	1573	2776

Table 2. Inferred pathways of entry for existing non-native species in 15 OTs at the sub-category level, colour coded according to risk level: yellow = 1 to 10, orange = 11 to 20, and red = 21 and above.

category	sub-category	Invertebrates	Vertebrates	Plants
RELEASE IN NATURE (1)	Biological control	25	3	0
	Erosion control/ dune stabilization (windbreaks, etc)	0	0	10
	Hunting in the wild	0	2	0
	Landscape/flora/fauna “improvement” in the wild	1	0	1
	Medical use	0	0	0
	Release in nature for use (other than above, e.g., fur, transport, medical use)	0	0	0
ESCAPE FROM CONFINEMENT (2)	Agriculture (including Biofuel feedstocks)	1	2	225
	Botanic garden	0	1	0
	Pet/aquarium/terrarium species (including live food for such species)	0	46	0
	Forestry (including afforestation or reforestation)	0	0	26
	Horticulture	2	0	763
	Ornamental purpose other than horticulture	0	0	110
TRANSPORT – **CONTAMINANT (3)**	Contaminant nursery material	122	3	88
	Food contaminant (including of live food)	196	0	1
	Contaminant on animals	4	0	2
	Parasites on animals (including species transported by host and vector)	46	0	0
	Contaminant on plants (except parasites, species transported by host/vector)	425	15	0
	Parasites on plants (including species transported by host and vector)	1	0	0
	Seed contaminant	17	0	217
	Timber trade	55	0	0
	Transportation of habitat material (soil, vegetation)	245	1	224
TRANSPORT – **STOWAWAY (4)**	Container/bulk	207	10	22
	Hitchhiker on boat	41	5	0
	Hitchhiker on plane	6	0	2
	Machinery/equipment	44	0	56
	Organic packing material	28	0	0
	People and their luggage/equipment (in particular tourism)	45	1	28
	Vehicles (car, train, …)	51	0	17

Commonest introduction pathways

Overall, 97% of non-native invertebrate species result from unintentional introductions, with 77% of these as transport contaminants and 23% as transport stowaways. The commonest transport contaminant pathway was of live plant material (425 introductions, comprising 38% of invertebrate introductions at the transport contaminant subcategory level). Most (80%) invertebrate introductions were insects and within this group five Orders are responsible for 83% of the introductions: the sucking bugs (Hemiptera: 178 introductions), flies (Diptera: 170 introductions), beetles (Coleoptera: 162 introductions), butterflies and moths (Lepidoptera: 86 introductions), and ants and wasps (Hymenoptera: 86 introductions). The Hymenoptera and Coleoptera Orders include both unintentionally introduced species such as the tramp ants and rove beetles, and species deliberately introduced as biological control agents, the parasitic wasps and ladybirds.

Both vertebrate and plant non-native species mainly result from intentional introductions (release in nature plus escape from confinement), comprising 58% and 71% of introductions at the category level, respectively.

For vertebrates this is primarily through the pet trade (46 introductions, comprising 85% of all intentional vertebrate introductions at the subcategory level) which is clearly implicated as an important pathway of introduction for new species. Of the 37% of unintentional introductions of vertebrates, 20% result from unintentional introduction as transport contaminants, in this case exclusively of live plant material, and 17% from transport stowaways.

Plants are primarily introduced through the horticulture trade as garden plants, with 763 introductions comprising 67% of all intentional introductions at the subcategory level. This compares with 225 introductions of plants for agriculture (20% of all intentional introductions at the subcategory level). Most agricultural importations would have occurred before 1980 and therefore been excluded from the database, and this is also true of introductions to botanical gardens. Unintentional introductions account for 29% of plant introductions overall, the commonest pathway being as transport stowaway of habitat material (composts and aggregate (34% of all intentional introductions at the subcategory level) followed by transport contaminant of seed (33% of all intentional introductions at the subcategory level).

Geographic distribution of non-native species

In terms of the geographic origin of non-native species the commonest was “widespread” with 66% of records, followed by Americas/Caribbean only with 15%, UK/Europe only with 3%, and Africa only and Asia/Oceania only both with 2%; see Table 3. “Other combination” was responsible for 12% and reflects distribution consisting of a combination of two or three of the regions, for example UK/Europe and Africa. The predominance of widespread distribution could be interpreted as indicating that global trade is more important than regional connections. However, most of the species in the databases were cosmopolitan and widespread pest species which could enter the introduction chain at any point and, without extensive field sampling, it is not possible to confirm whether they are entering it regionally or globally. Relatively few species with purely regional distributions to each territory are recorded in the databases, suggesting that global trade is the more likely conclusion.

Table 3. Geographic distribution of existing non-native species

Territory	Americas only	UK/Europe only	Africa only	Asia/Oceania only	Other combination	Widespread
Anguilla	32	0	0	0	4	94
Ascension	19	5	6	3	55	167
BAT	1	3	0	0	3	2
Bermuda	170	7	2	5	37	263
BIOT	9	0	9	11	19	158
BVI	19	0	0	0	3	121
Cayman Islands	33	1	0	1	11	125
Falkland Islands	23	29	0	1	49	112
Gibraltar	6	2	8	0	10	39
Montserrat	15	0	2	1	4	137
Pitcairn	1	0	0	9	13	173
St Helena	9	18	22	8	44	53
Tristan da Cunha	2	6	6	2	34	96
Turks and Caicos Islands	26	2	1	2	13	113
TOTAL	369	77	56	43	307	1665

Interception data and what it tells us

With the exception of St Helena, interception data was not collected in a formal standardised way in any of the other 14 Territories. St Helena has a comprehensive Microsoft Access database for border and post-border interceptions which includes statistics on fresh produce importation that allows it to be readily used for biosecurity indicators. Ascension Island has interception data resulting from a biosecurity review carried out by Biofume Pty Ltd of New Zealand in 2015 which included spot checks of imported cargo and shipping containers from the UK, US and St Helena. These data provided valuable information to validate some inferred pathways. In addition, the importance was made clear of fresh produce, shipping containers and vehicles as pathways of entry for a range of contaminant and stowaway species (invertebrate and vertebrate).

Interception data of varying quality was available for six other Territories: Bermuda, British Indian Ocean Territory, Cayman Islands, Falkland Islands, Tristan da Cunha and Turks and Caicos Islands. Collection was informal, anecdotal or had been documented for other purposes. For example, the Falkland Islands interception data was in the form of a list of specimens sent away for identification. The data lacked information on the frequency with which different species are intercepted as well as records of interceptions of species which don't require identification. Most of the interception data for Territories came from border inspections, usually of fresh produce and consequently this pathway is over-represented.

Despite its limitations, interception data can be valuable. It confirms the association of certain species with fresh produce and also provides new information. For example, spiders are generally considered most likely to arrive as transport stowaways, but in the Falklands a number of spiders have been intercepted from imported fresh produce originating in Chile. However, spiders are not commonly intercepted in St Helena from imported fresh produce originating in South Africa, and inspection effort in St Helena is equally or more rigorous than that in the Falklands. It is unclear if this is a reflection of different pre-border controls in Chile and South Africa, the speed or cleanliness of different modes of transport from Chile and South Africa, or a reflection of the different spider diversity in South America and southern Africa. Further work is required to resolve this question, but fresh produce is clearly a potentially important pathway for spiders in at least some situations.

A further comment on the limitations of the interception data was made by Fred Burton of the Department of Environment, Cayman Islands. Mr Burton noted that the risk rating on numbers of interceptions is probably distorted by the fact that plant importations and escapes are easier to detect and track than some animals, especially small arthropods. In addition, illegally imported vertebrates are considered under-reported by biosecurity officers in various OTs. The frequency of detection reflects the intensity of inspection and surveillance, and this is limited by available resources. For all Territories biosecurity presence tends to be concentrated at ports of entry where it is focused primarily on reducing the risk of agricultural pests. Environmental pests may be overlooked, and pathways such as the post and courier mail for internet sales may be open to undetected introductions.

How reliable is this analysis?

Two important aspects not included in the analysis due to time constraints were the confidence level with which any one species was assigned to a pathway, and the impact (invasiveness) of non-native species and which, if any, pathways are linked to most damaging species. This needs to be borne in mind when interpreting results.

The identification of the most likely pathway for any one species was not always easy, and this was especially so for non-native species which aren't recorded as invasive, pests or weeds. Note that the database includes all non-native species and not just invasive species as the focus was the pathway of introduction irrespective of any impact caused, the "openness" of the pathway being the relevant input for future horizon scanning exercises. One of the implications of this is that the pathway "Escape from confinement" includes a number of species that haven't actually escaped from confinement, or at least not yet and possibly never will, they have merely been recorded as introduced to the Territory. This is true of a number of garden plants and agricultural crops, for example. The deliberate release as opposed to the escape of non-native species into the wild, for example, liberation of pets into the wild, was also not specifically recorded.

For intentional introductions such as for many plant species, available information often listed many possible uses for some species: erosion control, shade, amenity, ornamental, sometimes medical, yielding edible fruit, etc. The problem was to decide why the species was introduced to any specific Territory in the first place, to pick the "most likely" pathway. Every attempt was made to source sufficient data to identify the actual or most likely pathway and avoid picking multiple pathways as much as possible, but in a number of cases several pathways had to be ticked. This was particularly so at the subcategory level. It was often possible to be confident how a species was most likely to be introduced at the category level,

intentionally or unintentionally, but less confident about details at the subcategory level, for example in the case of a transport stowaway, if it was most likely to stowaway on vehicles, machinery or in general cargo.

The invertebrates present a different problem in that for many species there was very little data available, and this is particularly true for the smaller arthropods and more obscure taxa. On-line information tends towards taxonomic classification and identification with relatively little on habitat, ecology and life cycle which could give clues as to how the species might enter a pathway. In these cases, information had to be generalised at the generic or even Family level. There was insufficient time to mine data, both in terms of when a species was first recorded in a Territory, as well as for details on behavioural ecology of more obscure taxa.

The date of 1980 was selected more or less arbitrarily as the cut-off date for data to avoid including historic pathways no longer relevant such as wooden hulled sailing ships, activities associated with economic activities such as whaling and sealing, and varying patterns of human settlement. Is this really a good cut-off date? That question was considered as the analysis was carried out for each Territory and no reason was found to change it: it made a good general fit with research effort in Territories such as St Helena and in the Caribbean, with agricultural or environmental surveys carried out well before and after the date, and with post-war change in activities in the Falklands. Data from BIOT data demonstrates that species may not enter the records for some years following introduction. In this case, it is known that there were no intentional introductions of pets and ornamental plants after 1971 and yet both of these pathways of entry are evidenced due to the inclusion of a number of species in the database as first recorded post-1980. This will be true for all Territotries to a greater or lesser extent.

The pathway classification used is that adopted by the Convention on Biological Diversity SBSTTA 18 classification (UNEP/CBD/SBSTTA/18/9/Asdd.1). Working definitions were developed in discussion with Kevin Smith of the IUCN and Olaf Booy of the NNSS, pending the finalisation of official definitions (work currently in progress). It became clear during this exercise that the classification system can be difficult to apply to real cases and also misses data relevant to developing practical policy decisions to mitigate the risk of introducing non-native species. One example is that of the many insects introduced as transport contaminants of live plants, where information on what the live plant was being introduced for – agriculture, horticulture, ornamental, forestry etc. – is lost. The categories also force artificial grouping of very different commodities, for example “habitat material” includes composts, aggregates, sand, gravel, hay and straw, wood chips and shavings, and topsoil.

Conclusions

In conclusion, overall the most risky pathway for introducing new species of non-native plant and invertebrate species is the intentional importation of live plants, from the point of view of the plant itself as a potential weed, and as a vector for contaminants such as invertebrates. Associated material such as soil and plant pots with imported garden plants increase the risk. For vertebrates, the pet trade stands out as the most risky pathway of introduction. As both are intentional there is potential for mitigation by regulation.

Data used in this pathway analysis have limitations and need to be interpreted with this in mind. It is a “quick and dirty” exercise carried out for a specific purpose, as input to horizon

scanning, and should only be used more widely with caution. Conclusions drawn at the higher level (category) are more robust than those at the lower subcategory level.

Annex 1.

Possible modes of entry of invasive non-native species to St Helena, from Dr R. Key.

Ecological Group	**Free-flying insects of all ecologies** - flies, bees, wasps, parasitoids, butterflies, moths, bugs, hoppers, lacewings, mantis, crickets - also web-spinning spiders that balloon	**Invertebrates dependent on structured vegetation.** Plant feeding invertebrates beetles, caterpillars, bugs, aphids, thrips, psocids. Foliage dwelling predatory invertebrates & web spinning spiders	**Moisture loving invertebrates of soil, detritus & moist crevices** - earthworms, flatworms, eelworms, woodlice, tallitrids, millipedes, centipedes, detritiphilous scavenger & predatory beetles, mites, springtails, fly larvae etc, slugs & snails, spiders	**Xerophilic ground, rock & crevice dwelling species** - beetles, bugs, cockroaches, earwigs, scorpion, centipede, millipedes, wolf & jumping web-spinning spiders, some snails, geckos	**Saproxylic species on decaying timber** - beetles, snails, mites, woodlice, thrips	**Saproxylic species on dry or living timber** - beetles, termites, wood-wasps	**Hole nesting insects** - solitary and colonial bees & wasps	**Freshwater life** - water snails, various aquatic worms, frogs, fish	**Species feeding on dung, carrion and putrescent material** - various fly families, dung & scavenger beetles	**Anthropophilic indoor species, including species associated with dry stored foodstuffs** - spiders, silverfish, psocids, cockroaches, beetles, moths, mites, geckos	**Biocontrol agents** predatory beetles & bugs, parasitoid flies & wasps, specific plant feeding insects, diseases of invertebrates	**Parasites of humans & livestock** - fleas, lice, ticks, mites, eelworms	**Web-spinning spiders**	**Slugs & snails**	**Feral birds & mammals** - songbirds, mynah bird, rats, mice, rabbits, goats	**Plant seeds**	**Fungi other than plant diseases**	**Plant diseases**
	x	x	x					(x)	(x)		x		x	x		x	x	x
	x			x						x			x			x		(x)
										x								(x)
												x				x		x
	x			x			x			x			x					
	x	x		(x)		x	x			x		x	x			x		
	x			x						x			x			x		
	x	x					x			x	x		x					

used vehicle interiors/exterior crevices etc, including adhering soil		x		(x)	x						x			x			x	x	x
Building materials																			
bricks, breeze blocks, aggregates, construction metals & plastics, reinforcing steel etc*		x		x	x			x			x			x	x		x		
any aggregates*				x	x									x	x		x		
imported timber*			x					x											
used construction machinery/vehicles														x			x		
Agriculture/Horticulture/Gardening																		**x**	**x**
used agricultural vehicles		x		(x)	x						x			x			x		x
live plants in soil		x	x	x						(x)		x		x	x		x	x	x
aquatic/marsh plants/watercress		x	x	x					x	(X)					x				
previously used gardening equipment*			x	(x)	x		(x)							x			x	x	x
old used timber constructed material - tools, sheds/coldframes etc		x		(x)	(x)	x	x	x			x			x	(x)		x	x	x
compost			(x)	x	x									x	x		x	x	x
imported with pets/agricultural livestock										x			x						
Associated with Ships/visiting Yachts																			
permanent dwellers aboard ships							x				x			x		x			
hitchhikers' in open space aboard ship entering at Ascension/Capetown docks etc		x			x			x			x			x			x		
decaying material aboard ship (livestock dung, dead rats, wet litter etc)decaying seaweed attached to ship's anchors or ropes? foul-water accumulations aboard ship - bilges, toilets etc				x						x								x	
clean-water accumulations aboard ship - rainwater puddles, toilets etc				(x)						x									
Deliberate introductions									x			x				x	x		