GEO BON

GEO BON TECHNICAL SERIES

2

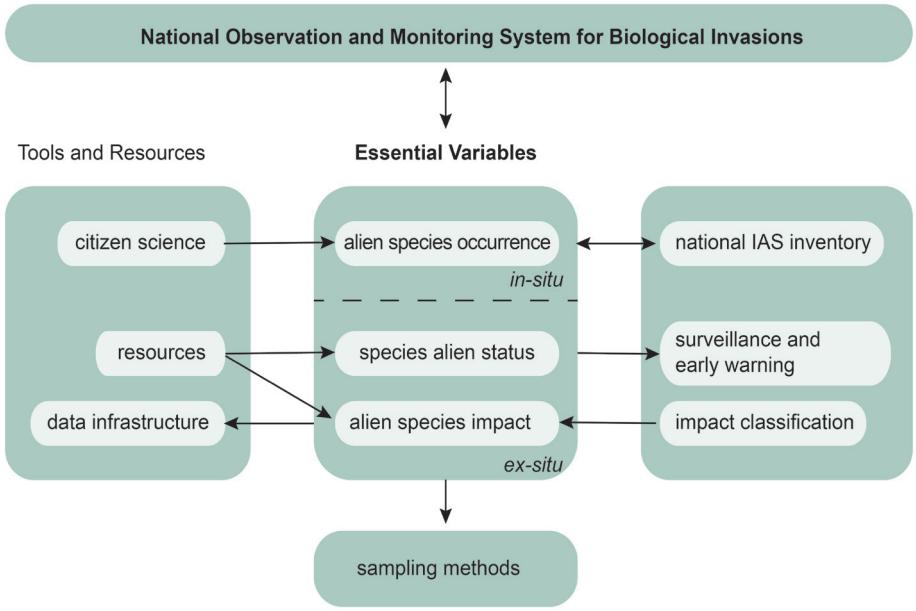
An Essential Biodiversity Variable Approach to Monitoring Biological Invasions: Guide for Countries

MONASH University

IUCN SSC Species Survival Commission ISSG Invasive Species Specialist Group

iDiv German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

Contents



This guide outlines how the use of essential variables for invasion monitoring, along with a modular approach to country development of observation and monitoring systems for biological invasions, provides an approach that is both feasible, scientifically sound, and policy and management-relevant.

01 The scientific basis

Invasive alien species (non-indigenous species whose introduction and/or spread threaten biological diversity) have significant negative impacts on biodiversity and ecosystems throughout the world. Species movements beyond their historic distributions are likely to continue. These movements are being driven largely by increased volumes of trade and increasingly complex trade routes. In many cases invasion and other forms of global change, such as climate change, interact to increase the likelihood of the establishment and spread of invasive species. Monitoring species movements and geography is essential to understand and track the consequences of biological invasion.

There is currently no global, systematic evaluation and monitoring process in place for invasive alien species. This is despite the fact that they pose a great risk to the environment and economies. Also, the variables and measures for monitoring invasions in a standardised way – needed to underpin a robust observation system – have until now not been fully developed or adopted. A global approach to invasion monitoring must also consider the highly uneven distribution of baseline information on invasive alien species and capacity across countries.

Many indicators have been developed for reporting on the state of invasion and its impact on biodiversity and ecosystems. In the past these have relied mainly on the collation of existing data across multiple sources, and often retrospective fitting of data for the purpose of delivering meaningful indicators. Available data are often highly fragmented. What is needed now is an approach to ensure that up-to-date, useful and accurate data on biological invasions are available to meet policy and management needs. A system that is sustainable, representative and robust is needed for informing country level and international policy and to prioritise where to invest in management.

Biodiversity science, and invasion biology specifically, has over the last few decades produced a wealth of conceptual and evidence-based knowledge on which to build a standardised observation and monitoring system for biological invasions. While the scientific underpinning for such a process and product is comprehensive, what has been lacking is applying this understanding to invasion monitoring at large scales.

Recent progress towards a global system of harmonized biodiversity observations uses the concept of Essential Biodiversity Variables (EBVs). EBVs provide the information needed for studying, reporting and managing environmental problems. The essential variables for invasion monitoring we present here fits within this broader EBV framework.

This document presents an overview of an EBV-based approach to develop national observation and monitoring systems for biological invasion. Using this approach and regardless of their baseline, countries can identify and prioritise invasive alien species and pathways[1], and report meaningfully on Aichi Target 9 (part of the Convention on Biological Diversity's Strategic Plan, see below).

THE POLICY CASE

The Strategic Plan for Biodiversity 2011–2020 and the 20 Aichi Targets[2] includes:

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02 Essential variables for monitoring invasions

There are a key set of measurements, or essential variables, that are needed to monitor biological invasions. Together these variables provide the minimum information set needed to assess and track the status of biological invasion. This is related to the idea of **Essential Biodiversity Variables**, which are the subset of biodiversity variables needed for studying, reporting and managing environmental problems[4].

The three essential variables for invasion monitoring are **(1) alien species occurrence**, the **(2) alien status of a species** and the **(3) impact that a species has** on biodiversity and ecosystems (see figure below).

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The **alien status of a species** is the second essential variable that an invasion monitoring system must deliver. Alien status provides information on whether a species is indigenous or non-native (alien) at any particular locality in which it is found. Information on the natural geographic range of a species provides important baseline information for determining if an alien species is inside or outside of its indigenous geographic range. Alien status information is also essential for designing appropriate policy and management responses[5].

The **impact that the alien species has** on biodiversity and ecosystems is the third essential variable in an invasion monitoring system. A standardised method for classifying alien species impacts across species and environments is needed to enable prioritisation of species for policy and management (see p. 4). A scheme for the classification of alien species according to the maximum realised size of their impact, The IUCN **Environmental Impact Classification for Alien Taxa** has now been developed[6]. It will shortly be available as a source of information on invasive alien species impacts for global and national use.

5. McGeoch, M.A., Spear, D., Kleynhans, E.J. and Marais, E. (2012) Uncertainty in invasive alien species listing. *Ecological Applications* 22, 959–971.
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Essential variables for monitoring invasions

Essential variable	Measurement and scalability	Guidelines for frequency of updates	Feasibility	Relevance to Aichi Target 9 and long-term monitoring of biological invasions
Alien species occurrence	Records of species presence or absence, scalable by increase in resolution of the record from country to georeferenced point locality.	1 to 5 years	Data are available for many species, some of which have global coverage data at a coarse resolution[7]. Uneven distribution of data quality across countries[5], to be improved using the systematic approach proposed here, supported by GIASIP initiative, species registries (see p. 7), citizen science and new technologies (see p. 8).	Target 9 refers to the identification and prioritisation of invasive alien species, the fundamental basis of which is determined by the presence of such species in a locality or associated with a pathway
Alien species status*	Categorical, yes/no, alien or indigenous (native)[6].	≥ 10 years	Well known for many of the species currently considered to be the worst invaders. Less well known for many smaller and more narrowly distributed alien species. This variable needs to be underpinned by sound taxonomy[9]. Molecular tools are increasingly able to support identification of species and the provenance of populations[10].	Target 9 refers to identification of invasive alien species
Alien species impact**	Species classified based on the size of their impacts, assessed against 10 standard impact mechanisms (see p. 4)	5 to 10 years	Theoretically well understood and widely appreciated, although not straightforward to measure. Recently proposed impact classification scheme (see p. 4) provides a solution for comparative, broad, taxonomic and geographic assessment.	Target 9 refers to prioritisation of invasive alien species, which requires an impact assessment and classification scheme that facilitates comparisons across species and environments

*The status of a species as either native or alien within any particular locality or region is considered ancillary information to the Essential Biodiversity Variable, species distribution. In the context of biological invasion this information takes on special significance as the essential basis upon which appropriate policy and management decisions are taken, along with the need to prioritize the collection and collation of these data (currently inadequate)[5], to support effective invasion management.

**Composed of information from multiple EBVs, this essential variable for invasion monitoring can be considered a derived variable or indicator within the EBV framework (see p. 4).

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03

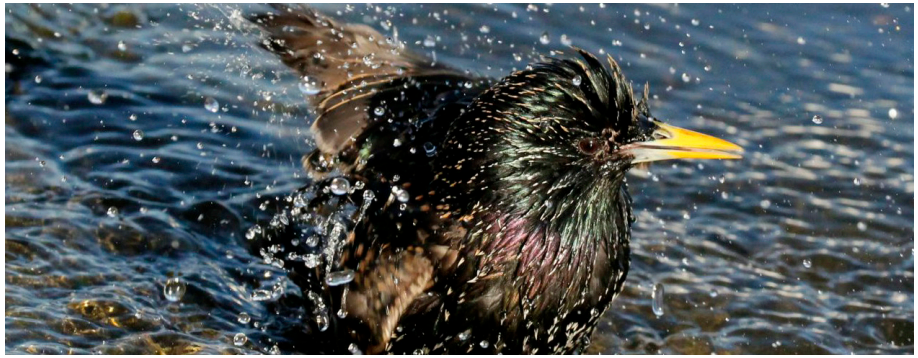
Impact classification of alien species

WHAT IS IT?

The **impacts of alien species** manifest in a variety of ways, and on different levels of biological organisation. To prioritise alien species, for management action or other reasons, we need a way to evaluate, compare and predict the size of the impacts of different alien species. A method to do exactly this, based on explicit, descriptive scenarios of impact by alien species defined in the International Union for the Conservation of Nature (IUCN) Global Invasive Species Database (GISD) has recently been published in the scientific literature[6,11]. The scenarios describe increasing levels of impact on native ecosystems under 10 mechanisms of impact. Linking impacts to scenarios in this way provides a transparent approach for assigning an alien species to one of five sequential categories of impact: **Minimal Concern, Minor, Moderate, Major,** and **Massive** (see Figure).

HOW CAN IT HELP?

Categorising alien species in this way has a number of practical benefits. Variation in impacts can be compared across taxa and space, and causes of this variation can be explored. A species' categorisation can feed into risk assessments and statutory regulations. Changes in categorisations over time can be used as an indicator of trends in alien species impacts (e.g. as required for Aichi Target 9 of the Convention on Biological Diversity's Strategic Plan 2020, see p. 1), at the regional, national or global level.



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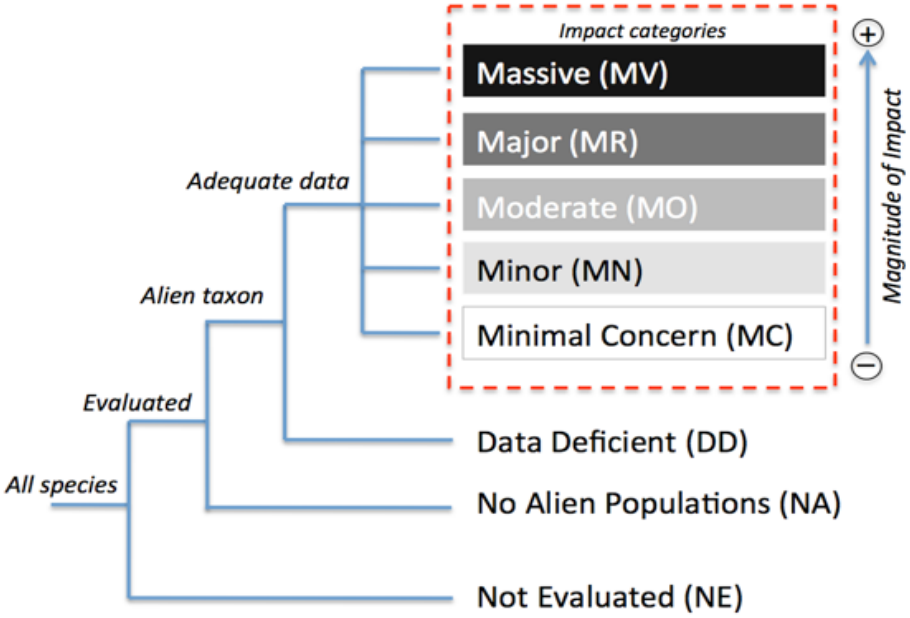
WHAT TO DO?

At present, a framework to ensure the consistent application of the classification scheme is being drafted, along with technical protocols for the assessment, review and quality assurance of the resulting classifications. The scheme is also undergoing a consultation phase with the main stakeholders (e.g. scientists, NGOs, IGOs, managers), to ensure that it meets their diverse needs, with the ultimate aim of having it adopted by the IUCN as their formal method for classifying alien species in terms of environmental impact.

Environmental impact classification for alien taxa



This figure (reproduced from[6]) shows the different categories in the alien species impact scheme, and the relationship between them. The process of categorisation is sequential: species are first evaluated for evidence of alien populations, then assessed for evidence of impact, and if any such evidence exists, categorised as to the magnitude of such impacts on the basis or semi-quantitative scenarios of impact.

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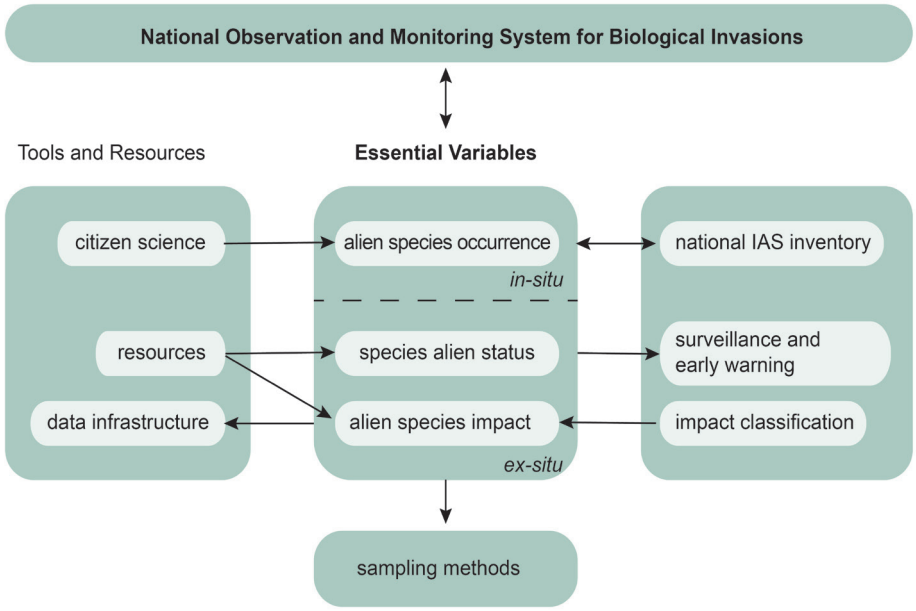

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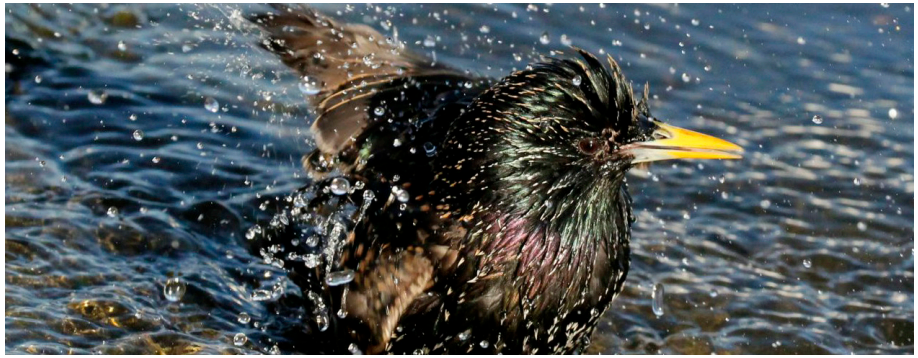

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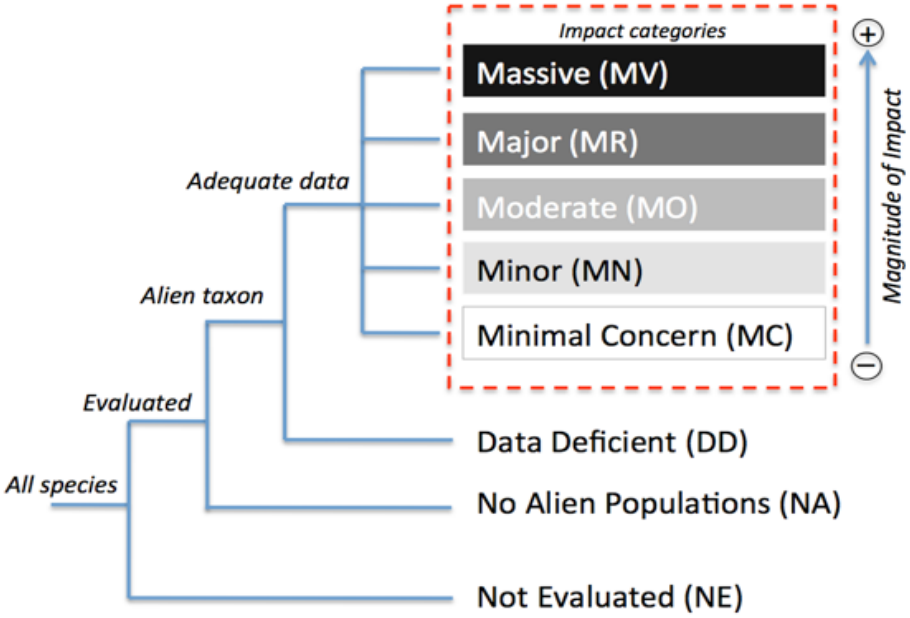

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04 Building country contributions for global monitoring of biological invasion

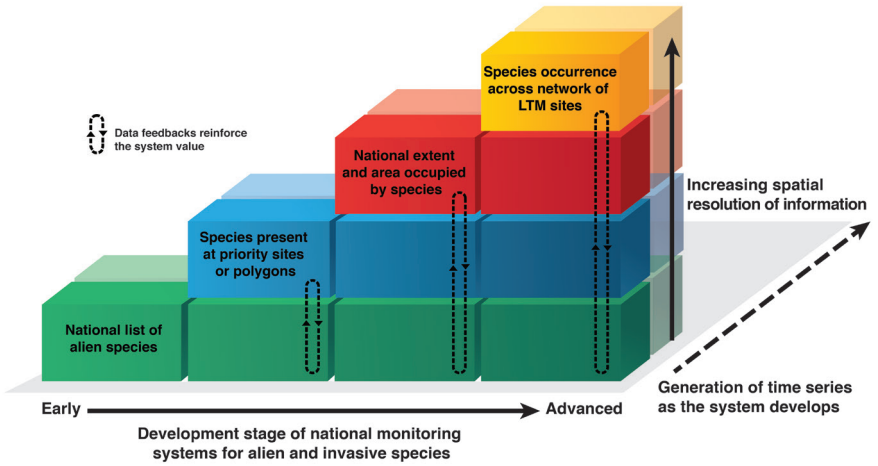
Countries need key information on invasive species to effectively manage their negative impacts. This information is also needed to report on progress towards achieving policy targets for biological invasion, including Aichi Target 9 (see p. 1). Country information is also essential for building a global understanding of biological invasion and how to deal with it strategically.

Some of the information on invasive alien species must be provided by countries themselves. The most essential variable that countries need to deliver themselves is **alien species occurrence**, that is, spatially georeferenced presence-absence records (see p. 2 - 3). These data can be generated at several possible scales and from a wide range of sources, including primary research and government and non-governmental organisations. However, these data often need to be collated from these sources to provide national level information.

Countries differ widely in the level of existing information on invasive species, and also in the resources and capacity available to generate new data and to collate existing data. Yet all countries can provide some information on the status of biological invasion. At the simplest level countries are called on to deliver a national inventory, or species list, of alien and invasive alien species present in the country (see p. 6)[12]. Countries can use available resources (see p. 7) to determine the **alien species status** of species present in the country. This forms the basis of a **national observation and monitoring system for biological invasion.** The system is then further developed by strategically adding priority sites into monitoring schemes, prioritising species based on the **impact that the species has**, generating national distribution data on invasive alien species and eventually including them in long term biodiversity monitoring networks (see p. 4).

Over time this information can be built on in a strategic and structured way to improve the quantity and coverage of information that feeds into the national observation and monitoring system (see figure).

Repeat and ongoing measurements of alien species occurrence over time are needed to track changes in the size of the problem, its impact on biodiversity and the effectiveness of efforts to deal with biological invasions [7, 13].



Modular approach to the development of national observation and monitoring system for biological invasions, built from the variable 'alien species occurence', which is one of the three essential variables for invasion monitoring and also an Essential Biodiversity Variable[4]. LTM: Long term monitoring.

12. UNEP, (2014) *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity XII/17,* Twelfth Meeting of the Conference of the parties to the Convention on Biological Diversity, UNEP/CBD/COP/DEC/XII/17, Pyeonchang, Republic of Korea.

13. Genovesi, P., Butchart, S.H.M., McGeoch, M.A. and Roy, D.B. (2013) Monitoring trends in biological invasion, its impact and policy responses In B. Collen, N. Pettorelli, S. Durant and J.E.M. Baillie (Eds.), *Biodiversity Monitoring and Conservation: Bridging the Gaps between Global Commitment and Local Action.* (pp. 138-158). Wiley-Blackwell, Cambridge. 10.1002/9781118490747.ch7.

05 National invasive alien species inventories

One of the essential requirements for countries to be in a position to accurately assess and report on progress toward meeting Aichi Target 9 under the Convention on Biological Diversity's (CBD) Strategic Plan for Biodiversity 2020, is an inventory (or list) of invasive alien species present in the country[12].

Baseline inventories can be established by drawing on a range of information sources, by combining **alien species occurrence** data collected in the field, with **alien status data** (see p. 2 - 3) which can be obtained from a variety of *ex-situ* sources if not already available (see p. 7).

There are many good examples of countries that have made progress towards national lists of alien and invasive alien species, including countries across a spectrum of economic development:

The Cook Islands have an online database that includes species occurrence (4213 species as of July 2015) and alien status data for some islands[14]. To develop a national inventory of alien and invasive alien species the Cook Islands need only to extract information on the invasiveness (from *ex-situ* sources such as http://www.cabi.org/isc/, see p.7) of these alien species and incorporate this information into the existing database. These species can then be categorised and prioritised based on the size of their negative impacts (**alien species impact**, see p. 4). In fact the Cook Islands have begun to prioritise invasive alien species and in their Fourth National Report for the CBD[15]. The country identifies and report on the plants (40 species, 6 of serious concern) and animals (22 species, 1 of serious concern) that the Islanders consider to be of most concern[14].

South Africa has recently produced a national list of regulated invasive alien species. Within the Alien and Invasive Species Regulations published in 2014[16], is a National List of Invasive Species (559 species) and a list of Prohibited Alien Species that may not be introduced into the country (560 species).

The Norwegian Biodiversity Information Centre (NBIC) provide a good example of how cooperative efforts between NGOs, government agencies and volunteers can lead to substantial country data on alien and invasive alien species. The NBIC offers a data platform for species observations and for monitoring invasive alien species into the future. Launched in 2008, they now have over 10 million species occurrence records, including an invasive alien species inventory. These alien species have also been categorised according to their potential to negatively impact native ecosystems[17,18].

14. http://www.cookislands.bishopmuseum.org
15. https://www.cbd.int/reports/nr4/default.shtml

16. http://www.invasives.org.za/item/469-new-nemba-regulations-published.html.
17. Gederaas, L., Moen, T.L., Skjelseth, S., and Larsen, L.K. (eds.). *Alien species in Norway – with the Norwegian Black List 2012.* The Norwegian Biodiversity Information Centre, Norway.
18. http://www.biodiversity.no/

06

Resources to support invasion monitoring

RESOURCE	HOW CAN IT HELP	LINK
Global Invasive Alien Species Information Partnership **(GIASIP)**	Provides links to: • identification tools and resources • existing information on species distributions • some species presence records • locating an expert with skills that fit your particular need or interest • a forum for discussion • glossaries	http://giasipartnership.myspecies.info/en
Invasive Species Specialist Group **(ISSG: IUCN Species Survival Commission)**	• Provides technical and scientific advice to IUCN members, and national and regional agencies to develop policy and strategies to manage the risk of biological invasions • Has developed a prototype resource for managing invasive species pathways[19]	http://www.issg.org/
Global Biodiversity Information Facility **(GBIF)**	• Encourages and provides common standards, for data publishing and management, to maximize its value • Provides taxonomic and geo-referenced primary species occurrence data (distribution records), which can be explored in multiple ways, including by country	http://www.gbif.org/
Invasive Species Compendium **(ISC: CABI)**	• Provides an authoritative source of evidence-based information on alien and invasive alien species, including datasheets on over 1500 invasive alien species and animal diseases, countries, habitats and pathways • Includes distributional information and maps	http://www.cabi.org/isc/
Global Invasive Species Database **(GISD)**	• Provides species based taxonomic and ecological information and country level distribution records • Provides a summary of management options available • In the process of enhancing database interoperability via GIASIP [19]	http://www.iucngisd.org
Global Register of Introduced and Invasive Species **(GRIIS)**	• Compilation of known introduced and invasive alien species, with verified inventories for > 102 countries, under development [19]	http://www.griis.org/ (under development)
World Register of Introduced Marine Species **(WRIMS)**	• Includes more than 1400 introduced species worldwide • Lists the known alien marine species worldwide, with an indication of the region in which they are considered to be alien • Lists whether a species is reported to have ecological or economic impacts and thus considered invasive in that area	http://www.marinespecies.org/introduced/
Convention on Biological Diversity **(CBD)**	• Provides access to recent and past developments on invasive alien species under the CBD • Defines terms related to the issue of invasive alien species under the CBD • Provide a guide for understanding and addressing Aichi Target 9	http://www.cbd.int/invasive/

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07

Citizen science to support invasion monitoring

WHAT IS IT?

Citizen science is the involvement of volunteers in the scientific process. Although this term is new, people have been monitoring biodiversity in a voluntary capacity for centuries[20]. In fact much of our understanding of the large-scale distribution patterns of wildlife relies on so called "citizen scientists" who have gathered information on the **occurrence** of species around the world. Citizen science also has particular relevance for invasive alien species, where the monitoring and surveillance required for early warning of new arrivals is so important. Historically most of the volunteers have been taxonomic experts, but more recently participation has widened to include non-experts of all ages. Indeed citizen science seems to have undergone a dramatic increase in popularity and there has been an escalation in the diversity and number of citizen science projects over the last decade. New technologies, such as online recording and smart phone apps, have undoubtedly been hugely influential in the rise of citizen science. They have also enabled rapid reporting and the capacity to cross check data for quality (such as via submission of high resolution photographs for verification by an expert and the capture of automated spatial references using the GPS within smart phones).

Anyone can get involved with citizen science and there are so many ways people can contribute to monitoring biological invasion, from simple mass participation initiatives to systematic repeat surveys.

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HOW CAN IT HELP?

Anyone can get involved with citizen science and there are so many ways people can contribute to monitoring alien species, from simple mass participation initiatives to systematic repeat surveys[21]. Guidelines on how and when to use citizen science have also been developed[22-24]. Mass participation citizen science can rapidly provide invaluable data on spatial scales that would otherwise be unachievable. One of the greatest benefits of citizen science is the opportunity to engage participants in discussions on complex scientific issues, and a number of studies have demonstrated changes in behaviour as a consequence of involvement in citizen science.

WEBLINKS

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2. http://www.ceh.ac.uk/news-and-media/news/mobile-phone-app-help-monitor-uks-native-lady-birds-after-foreign-invasion
3. http://www.education.nationalgeographic.com/education/idea/citizen-science-projects/?ar_a=1

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22. Pocock, M.J.O., Chapman, D.S., Sheppard, L.J. and Roy, H.E. (2014) Choosing and using citizen science: a guide to when and how to use citizen science to monitor biodiversity and the environment. Wallingford, NERC/Centre for Ecology & Hydrology, 24pp.
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08

Sampling methods for monitoring alien and invasive alien species

The quality of the data generated by monitoring alien and invasive species will determine how useful it is for policy and management. It goes without saying that the design and operation of surveillance and monitoring schemes must be cost-effective, efficient and fit for purpose[25].

Perhaps most importantly the method must be designed specifically to address the aim of the surveillance or monitoring program. This aim should be articulated clearly and in some detail at the start of any monitoring project. For example, the aim might be to simply generate a list of alien species with the intention of updating it over time, or to carry out field surveys for the early detection of new invaders. The aim could also be to contribute baseline and repeat observations as part of a **national observation and monitoring system for biological invasions.**

An important principle in biodiversity observation and monitoring is to ensure that the methods used are transparent and repeatable. In other words the methods should be well documented, well archived and readily accessible to anyone that may want to repeat them or apply the same methods elsewhere. Recognising the strengths and weaknesses of a monitoring program is important.

The process of listing alien species involves up to 10 different potential forms of uncertainty that affect how the content of the list is interpreted[5]. For example, the historical indigenous geographic ranges of species are often uncertain, which affects the accuracy of **alien species status** information. Even the taxonomic identities of alien species are sometimes not well known.

Decisions can be made to optimize the cost effectiveness and efficiency of surveys for invasive alien species, by selecting particular spatial arrangements, sampling density and using fixed versus temporally dynamic survey designs for particular areas[26].

Standardizing measurements for monitoring invasion are also important for comparing results across species and areas and over time (see p. 5)[8, 27].There are a wealth of resources and expertise available for informing the design of observation and monitoring systems for alien and invasive alien species. Some of these are mentioned in this section and elsewhere in this guide (see p. 7). The guidance from the essential variables for invasion monitoring (see p. 2 - 3), and the modular approach to building a **national observation and monitoring system** (see p. 5) provide a broad framework and clear direction for countries to achieve local monitoring objectives for biological invasions, and to contribute to global monitoring efforts.

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09

Surveillance and early warning

Early warning systems are an important component of strategies to limit biological invasions. If an incursion is detected before substantial spread has occurred the probability of eradication will be high, management costs minimal and overall impact low. To achieve this, specific resources can be allocated to monitor:

- particular high-risk pathways of introduction;
- locations where introductions, establishment and invasions are higher than others, such as invasion hot-spots; and
- particular species (e.g. insect pheromone traps set up at ports to detect particular insect pests)

Such active surveillance can be expensive, but identification is usually reliable and there will be good data on sampling effort[28].

If an incursion of an invasive alien species is detected before substantial spread has occurred, the probability of eradication will be high, management costs minimal and overall impact low.

By contrast, passive surveillance schemes depend on people opportunistically noticing and reporting taxa. Communication material can be distributed to encourage reporting of particular species; formal spotter networks can be set up to increase the level of observation in an area; and resources can be dedicated to co-ordinate information submitted from the general public (e.g. UK Ladybird survey website to track the invasions of Harlequin ladybird http://www.ladybird-survey.org).

Passive surveillance is usually much cheaper than active surveillance, and a greater area can be covered. However, it can require substantial co-ordination, there are likely to be many false positives and sampling effort is highly variable such that likely sites of introduction might not be well sampled.

The balance between active and passive surveillance depends on how easy it is for an observer to spot and identify an invader; what biases there are in reporting; and how quickly the information is needed for action to be effective. Of course detection is the first step. Thereafter, resources are required to confirm the identity, the risks posed, and to organise the response.

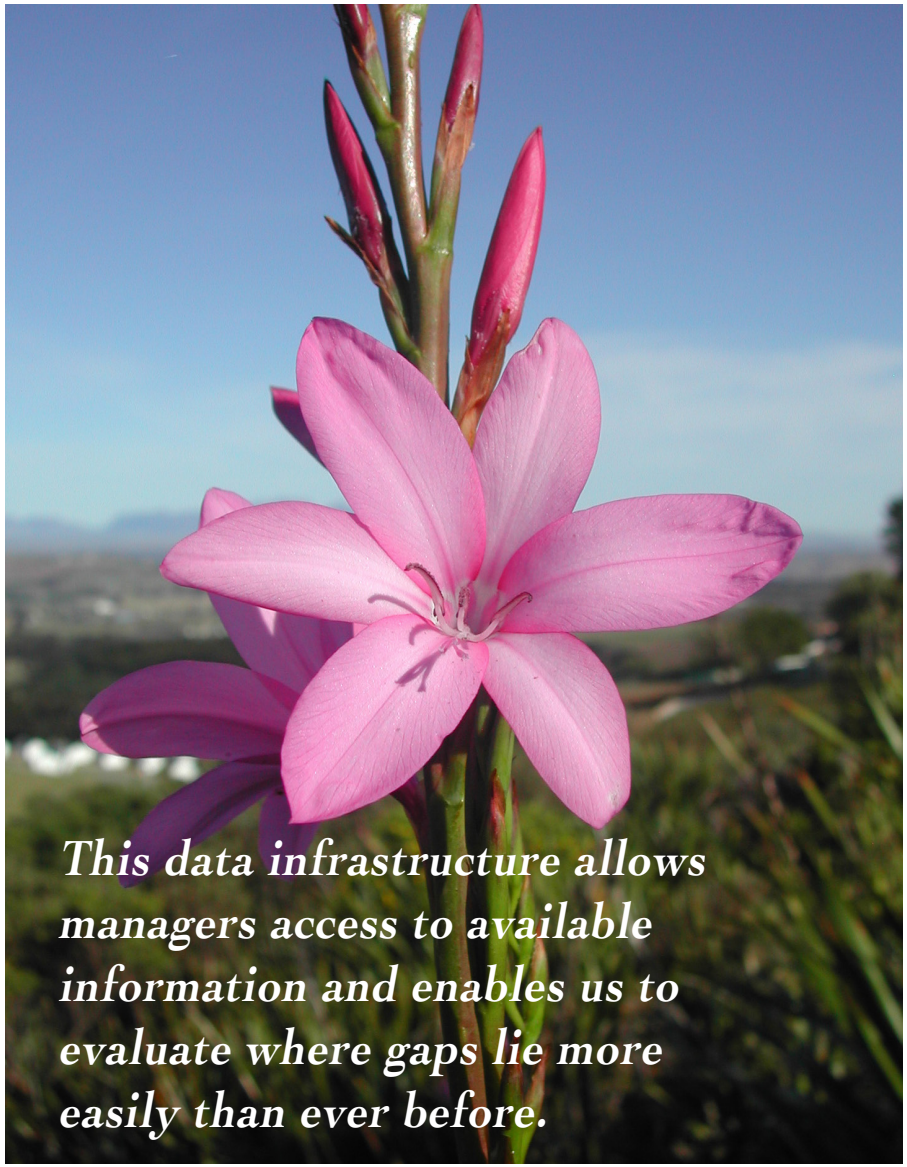
Active Surveillance	Passive Surveillance
Can be targeted to high risk pathways, invasion hot-spots and / or high risk species	Requires substantial coordination so that the maximum benefit is gained from *ad hoc* observations
Species identification is usually reliable	Can result in many false positive records
Known sampling effort	Coverage is variable
More costly	Less costly
Usually only covers small areas	Can cover large areas

28. Welch, B.A., Geissler, P.H., and Latham, P. (2014) Early detection of invasive plants - Principles and practices: U.S. Geological Survey Scientific Investigations Report 2012–5162, 193 p., http://dx.doi.org/10.3133/sir20125162

Data infrastructure to support invasion monitoring

In the past field data on the **occurrence of invasive species**, which can be painstaking and expensive to collect, has been collected on an *ad hoc* basis. Often these data have not been accessible to managers, scientists and governments outside of the organisation in which it was collected. However, with the increased use of the online tools to manage and share data, good progress has been made in the digital organisation and sharing of existing information. These online data platforms provide the necessary data infrastructure to ensure that the maximum value is gained from every data point collected (see p. 7) [19, 29].

For example, the Global Invasive Alien Species Information Partnership (GIASIP) provides a freely accessible platform for data sharing and data integration and is a central repository for **alien invasive species status** information. It also includes a number of data training tools and species identification guides. The Map of Life (https://mol.org/) connects species records with spatial information, and The Global Registry of Introduced and Invasive Species (GRIIS) are close to providing accessible archives of verified national inventories. The Global Biodiversity Information Facility (GBIF) includes distribution data for half of the world's species. The World Register of Introduced Marine Species (WRIMS) records the presence and location of 1644 (as of September, 2015) alien marine species. There are also a number of resources available for managers to assess the risk of biological invasions, the potential impacts of invasive species and to deal with taxonomic and species identification problems (see p. 7). Guidelines for data sharing are also available[30]. This data infrastructure allows managers access to available information and enables us to evaluate where gaps lie more easily than ever before.



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11 Glossary

Alien species:
Species whose presence in a region is attributable to human actions that have enabled the species to overcome fundamental biogeographical barriers (i.e. human – mediated, extra - range dispersal)[31]

Essential Biodiversity Variables:
The measurements required for the study, reporting, and management of biodiversity change.[4]

Impact:
Measurable changes to the properties of an ecosystem by an alien species[11]

Invasive alien species:
An alien species whose introduction and/or spread threaten biological diversity (the term "invasive alien species" is the same as "alien invasive species", see decision V/8 of the Conference of the Parties to the Convention on Biological Diversity (http://www.cbd.int/invasive/terms.shtml)

Observation:
An individual measurement or record that is taken for the purpose of quantifying an event or property of the environment

Occurrence:
The presence in an area or at a site of an individual of any species. 'Occurrence' and 'occupancy' are closely related terms, sometimes used interchangeably

Occupancy:
A variable that measures the presence and absence of a species at a site or in an area of interest. It is simply the presence or absence of a species from one place, or the number of sites at which a species is present within an area. 'Occurrence' and 'occupancy' are closely related terms, sometimes used interchangeably.

Monitoring:
Intermittent (regular or irregular) series of observations in time, carried out to show the extent of compliance with a formulated standard or degree of deviation from an expected norm[32]

Prioritization:
The process of ranking species, pathways, or sites for environmental impacts and for deciding on actions to effectively and efficiently prevent or mitigate the impact of invasive alien species[1]

Priority species:
Priority species are those that are identified as posing the greatest risk to biodiversity or the greatest opportunities for preventing such risk

Pathway:
Any means that allows the entry or spread of an alien species into a region[33]

Surveillance:
An official process by which data on species occurrence are collected and recorded using surveys, monitoring or other procedures

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Follow developments of the vision for global monitoring of biological invasions and additional background information and publications at this site

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