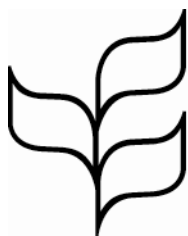




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Items 12 and 16 of the provisional agenda*

**INVASIVE ALIEN SPECIES: DATA ACCESS AND USE FOR RESEARCH TOWARDS
ACHIEVING AICHI BIODIVERSITY TARGET 9**

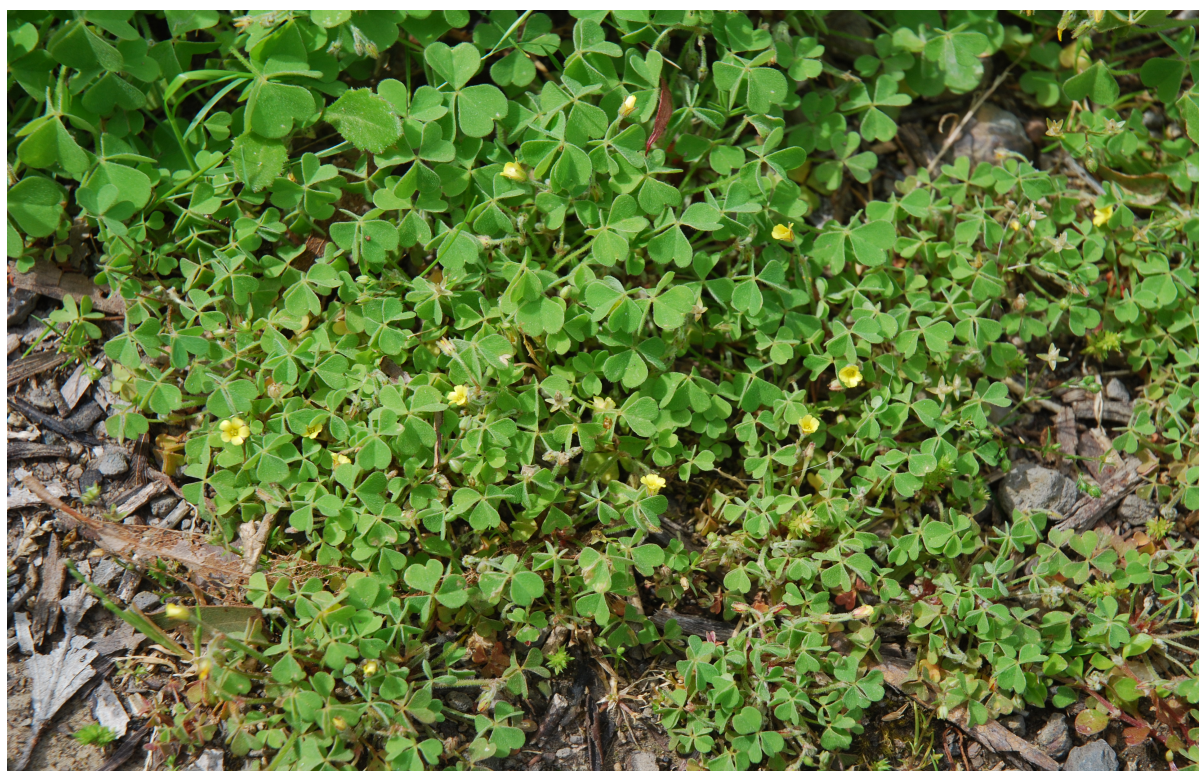
Note by the Executive Secretary

1. The Executive Secretary is circulating herewith, for the information of participants in the thirteenth meeting of the Conference of the Parties, a report prepared by the Global Biodiversity Information Facility (GBIF), through its Task Group on Data Fitness for Use in Research on Alien and Invasive Species, which contains information relevant to deliberations on the development of decision support tools in the context of decision XII/17.
3. The report is being circulated in the form and language in which it was received by the Secretariat.

* UNEP/CBD/COP/13/1.

Data fitness for use in research on alien and invasive species

Final task group report
November 2016



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Usage of the terms ‘alien’ and ‘invasive’ in this report

The phrase ‘alien and invasive species’ (abbreviated as A&IS) is used throughout this document rather than the phrase ‘invasive alien species’ (IAS) as used by the Convention on Biological Diversity (CBD) (and whose definitions we adopt here). The reason for this is that not all alien species have negative environmental or socio-economic impacts and according to the CBD definition are therefore not invasive. This distinction is relevant to the purpose of this task group.

Cover Image

Oxalis micrantha is a native to Argentina, Chile and Peru and is also invasive in California. During a side event of the Task Group meeting in Melbourne, this species was discovered in Australia for the first time. The Parks Department are now considering how to eradicate it, before it spreads further. *Oxalis* is one of the weediest plant genera and it goes to show how important vigilance, communication and a rapid response are, if we are to control the spread of invasive species. Photo: Quentin Groom, 2016

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Executive Summary

The discovery, access and appropriate use of primary biodiversity data are critical for alien and invasive species (A&IS) research at continental, regional, country and subnational scales. **Sustainable, reliable, timely, and accessible data on A&IS is essential to the long-term management of this key threat** to biodiversity, including the ability of countries to meet the Honolulu Challenge (<https://www.iucn.org/theme/species/our-work/invasive-species/honolulu-challenge-invasive-alien-species>) and to achieve Aichi Target 9 of the Strategic Plan for Biodiversity 2011-2020 (<https://www.cbd.int/sp/targets/rationale/target-9>).

GBIF **provides a range of essential information services** for A&IS researchers, including but not limited to taxonomic and occurrence information. The Task Group on Data Fitness for Use for A&IS aimed to capture the best available experiences, document limitations in existing GBIF services and suggest improvements in the functionality of GBIF.org to support domain-specific needs for research on A&IS. While the Task Group focused on the needs of research, we also considered the best means of organizing data useful for (a) policy needs, such as indicators of progress towards the *Aichi Biodiversity Target 9* and the recording of Essential Biodiversity Variables (EBVs) and (b) advancing and evaluating diverse management applications, such as alerts, detection strategies, and risk assessments.

After broad consultation with the research and A&IS community, a suite of recommendations were identified under five broad topic areas: 1) Strategic approaches, 2) Improving existing data, 3) Expanding information content, 4) Functionality, and 5) Communication and engagement. Several recommendations are relevant for other data users, but the **availability, quality and timeliness of these data are especially critical for A&IS** because of the real-world consequences resulting from the negative impacts of biological invasions.

Five priority recommendations were distilled that could form the basis of a strategy for the GBIF network to improve data fitness for use for A&IS research. In summary GBIF could:

1. Increase its capacity as an essential hub for open access A&IS information
2. Increase communication with national nodes to improve data coverage
3. Improve functionality and visibility of A&IS information
4. Support the enhancement, development and adoption of relevant data standards
5. Focus on data and information improvements essential to A&IS research, including extent and currency of occurrence data, geographic origin, native and non-native ranges at species and record levels, information on mechanisms of introduction, and data quality enhancements

Alien species occurrence includes *taxonomically verified species presence records or absence information at a locality with a geographic coordinate, or in a prescribed area, such as a management or geopolitical unit or site* (Latombe et al. 2016). Alien species occurrence information is the **single most important variable** necessary to support research, monitoring and management of A&IS. It is also one that requires in-situ collection from countries. Such data are the core of GBIF's mandate, and GBIF is best positioned to house open access information of this nature, for both countries with and without the capacity to do

so themselves. We therefore cannot emphasize more strongly how important GBIF is to this endeavour.

In conclusion, GBIF plays a pivotal role in the provision and hosting of data on A&IS. As a stable and experienced host of global open-access species information, it is a unique and widely relied upon source of information on the taxonomy and occurrence of A&IS. Together with relevant partners and the recommendations made in this report, GBIF will expand its role as a critical resource that is **instrumental to the ongoing delivery of the information needed** to minimize the introduction, spread and negative impacts of A&IS.

Introduction

Biological invasion by alien species is a significant force of change, affecting the structure and function of terrestrial, freshwater, and marine ecosystems across the globe. Invasions result when species colonize (due to human-mediated transfers that breach historical dispersal barriers, such as oceans and continents) and establish self-sustaining populations beyond their historical biogeographic ranges. A subset of these alien species is known to have severe impacts, including biodiversity loss (local-to-global extinctions), population declines, habitat alteration, change in ecological processes, and disruption of ecosystem services.

Invasion science is a multidisciplinary field that seeks to understand the biology, ecology, distribution, impacts, and management of biological invasions by alien species. The field includes both fundamental and applied research. The fundamental science tests classical questions about species assembly, population and community ecology, evolutionary biology, interaction strength, and ecosystem function. The applied science evaluates strategies to limit and manage (control) invasion impacts. These data is used to both inform and evaluate diverse management and policy frameworks on national, regional, and international scales.

At its core, invasion science concerns the distribution of species in space and time. There is high demand for occurrence data by a diverse community of end-users engaged in invasion science as well as biosecurity activities to detect and prevent invasions. Importantly, there is also a high premium on increased global coverage and rapid reporting of new occurrence records for A&IS, because (a) invasive species are expanding rapidly in recent time (driven by the increasing magnitude, rate, and global scale of trade), (b) effective conservation and management actions depend on near real-time data for rapid assessment and response, and (c) A&IS research and management in one country often depends on insights and data from other countries where the taxon concerned is native or alien.

Currently, data coverage for occurrence records of alien species is lean and decentralized, often not open access, and suffers from significant time lags, hampering research and management and policy responses in several respects. First, empirical measures and robust predictions (e.g., environmental niche models) for potential ranges, including responses to climate change, rely on extensive occurrence data (Feeley & Silman 2011, Latombe et al. 2016). Second, assessing patterns of spread and potential risk of invasions to new regions requires both knowledge about their current distribution, as well as the mechanisms of

introduction (pathways and vectors¹) (e.g. Ruiz et al. 2011, UNEP 2014). These data inform basic science and also biosecurity actions, including surveillance to detect and prevent new incursions. Third, occurrence records also serve to assess performance of management and policy to reduce invasion impacts (Carlton & Ruiz 2005).

Such assessments are increasingly required under individual (state and national) jurisdictions and international agreements, including the Convention on Biological Diversity (CBD) national reporting on progress made towards achieving Aichi Biodiversity Target 9 (CBD 2016). The recent IUCN **Honolulu Challenge** (<https://www.iucn.org/theme/species/our-work/invasive-species/honolulu-challenge-invasive-alien-species>) calls for bold action on invasive alien species. One of the essential needs for meeting this challenge is recognised as “**enabling enhanced knowledge on invasive and alien species...through investment in data collection, standardization and open access**”. GBIF is well positioned to contribute significantly to meeting this Challenge.

GBIF convened a task group to evaluate fitness for use of GBIF-mediated data resources to address research on A&IS and to contribute to meeting existing needs for data in this topic area (<http://www.gbif.org/newsroom/news/invasive-alien-species-task-group-launched>). The overall goal of this report is to outline the current and potential roles of GBIF in the area of A&IS resulting from this evaluation.

Objectives

This report addresses three specific objectives, as outlined in the terms of reference for the task group (<http://www.gbif.org/resource/82783>), including:

1. Based on domain-specific data use experience, to make recommendations on improving data availability and data use, data mobilization, data and metadata publishing, and data processing.
2. To document best practices from ongoing initiatives using A&IS-related data, and to collect information on repeatable tools (such as data filters) and data management solutions.
3. Based on information from GBIF Secretariat about current developments relating to quality and fitness for use, to make recommendations for GBIF.org improvements on enhancing existing functions and current activities.

General Approach

The recommendations outlined and discussed below are the result of the work of this Task Group on Data Fitness for Use for Alien and Invasive Species. They were derived from discussion amongst members of the Task Group as well as suggestions and comments obtained from respondents to a survey designed for this purpose (see outcome in following section).

¹ The terms pathway and vector are used interchangeably in this report, while we promote working towards the widespread adoption of the categorization scheme promoted in UNEP (2014).

In addition, the task group identified a number of relevant current activities, initiatives and stakeholders. These include

- *Aichi Target 9* of the Strategic Plan for Biodiversity 2011-2020
- The *Global Register for Introduced and Invasive Species* (<http://www.griis.org>), led by IUCN SSC Invasive Species Specialist Group (ISSG)
- The multi-partner *Essential Variables for Invasion Monitoring and Reporting* initiative (www.invasionevs.com)
- The proposed Darwin Core standard extension including terms and vocabularies of the Biodiversity Information Standards organization (www.tdwg.org) specifically for A&IS data
- The GEO BON Species Populations Working Group and Essential Biodiversity Variable-related activities, especially the Species Distribution EBV (<http://geobon.org/essential-biodiversity-variables/what-are-ebvs/>)
- The impact and pathway classification schemes being developed and promoted by ISSG and research partners (UNEP 2014), especially the Global Invasive Alien Species Information Partnership (GIASIP) (<http://giasipartnership.myspecies.info/en>)

Finally, the Task Group met with the **Biodiversity Data Quality Interest Group of GBIF and TDWG** (<http://www.tdwg.org/activities/biodiversity-data-quality/interest-group-charter/>). The data-quality topics discussed with the interest group, and which are outlined in further detail elsewhere in this report, included:

- Archiving research data and the challenge of locating and absorbing data and metadata
- The inadequacy of Darwin Core terms to capture information mandatory for evaluation of invasions, such as dates of introduction and terms associated with checklists
- Checklists and the need for quality assurance, including for taxonomic identifications and uncertainty attributes (see Chapman (2005) *Principles and Methods of Data Cleaning: Primary Species and Species-Occurrence Data*, available at <http://www.gbif.org/resource/80528>, for relevant approaches)
- The recording of attributes at taxon level and the value of some derived information presented as shape files
- The data-quality solutions used by the Atlas of Living Australia (<http://www.ala.org.au>) to deal with A&IS data quality assertion needs, including the use of standard annotations (see <http://dx.plos.org/10.1371/journal.pone.0076093>)
- eDNA and the large quantity of A&IS relevant data largely without taxonomic names

The contributions from the multiple sources outlined above were all taken into consideration in formulating the recommendations presented in this report.

Survey and publications using GBIF-mediated data on A&IS

Method

A survey was designed and initially circulated to a group of targeted researchers ($n = \sim 60$) that represent the relevant community and encompass expertise across realms, taxa and geographic regions (see *Appendix A*). This survey to targeted researchers ran for the month of August 2016, after which it was opened and circulated to interested members of the broader community for response (via GBIF Nodes and other communication channels, the Aliens-L list-server managed by ISSG, at the Alien Challenge COST Action at the Neobiota conference).

The survey provided the primary avenue of intended liaison with other experts to define the data use priorities essential for the A&IS research community. It constitutes widespread consultation and determines key questions that need to be addressed for the A&IS community on data availability and data use, including improvements in discovery and access, data mobilization, data and metadata publishing, and data processing at institutional, national, regional, and global levels (*Appendix A*). The feedback received via this route is integrated into the recommendations for improvements to GBIF.org functionality for A&IS.

Quantitative survey results

We received a total of 182 responses (137 were fully completed) from a wide range of A&IS researchers (*Appendix A*). The majority of respondents (87%) work for non-commercial organizations, but they were well distributed across terrestrial, freshwater and marine realms interested in a wide range of organisms and research topics. A minority (17%) reported that they regularly used GBIF, and 27% reported that they had published papers with GBIF-mediated data.

The A&IS community has quite broad requirements for use of GBIF-mediated data; all the suggested improvements in the questionnaire are required to some extent. However, the most important requirements were the **provision of information on native ranges**. There are also some more subtle differences between GBIF users, depending on their background. A cluster analysis of the questionnaire results indicated the **presence of two types of user** (*Appendix A*).

One group of respondents uses the GBIF API (Application Programming Interface: <http://www.gbif.org/developer/summary>) for species distribution modelling. They are less interested in invasion impacts and management, but they are more likely to have published scientific papers from GBIF-mediated data. Over 350 publications on A&IS related studies have used data from the network accessed through GBIF, covering diverse taxa and topics in terrestrial, freshwater, and marine realms. It is thus evident that GBIF provides a resource used widely across many disciplines in the A&IS research community. A word cloud created by using the titles and keywords of these selected publications visualizes the relatively prominent terms likely to indicate user groups. This exercise revealed that species distribution modelling was the dominant use of GBIF-accessed data in research publications (*Figure 1*).

by country and management options. Respondents requested a range of additional life history information such as habitat use, physiology and other species traits.

4. Suggestions for expanded functionality included requests for additional and more flexible **data filters**, and improvements in the **ease and fitness for use of data extraction** by filter.
5. Expanded functionality on **error descriptions and reporting**, and the possibility of a **surveillance or rapid response/reporting tool** were also suggested (see comments on range dynamics above).
6. The important role of GBIF to contribute to the formulation of **data standards for A&IS** was highlighted.
7. The viewpoint that GBIF could do more to **improve its visibility** as a provider of A&IS data was fairly common, and that it could actively advertise and engage with a range of relevant potential partners, related activities and data providers.

Topic areas and recommendations

The full suite of recommendations that emerged were integrated and grouped into five topic areas, that if implemented will significantly improve data fitness for use for A&IS across multiple relevant applications and outputs (*Figure 2*): 1) Strategic approaches, 2) Improving existing data, 3) Expanding information content, 4) Functionality, and 5) Communication and engagement. The sections below identify a comprehensive range of topic-specific and prioritized recommendations in each of these five areas. Some of the background and rationale supporting these recommendations are provided in further detail in *Appendix B*.

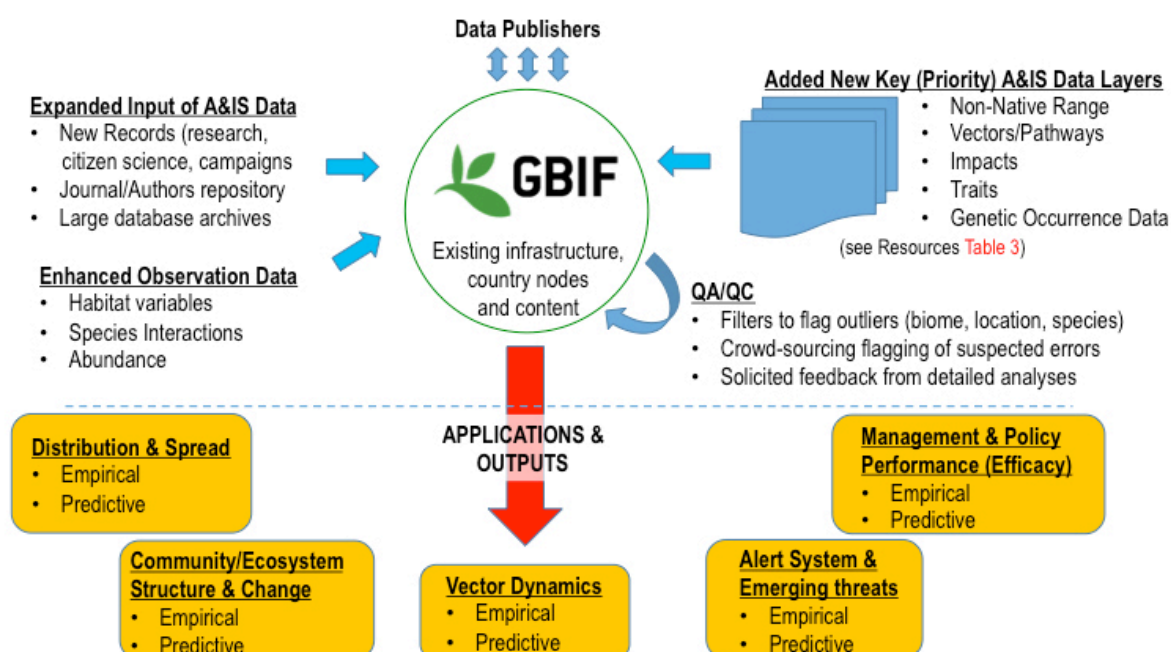


Figure 2: Overview of data inputs, enhancements and new functions for GBIF (top of figure) to increase data fitness for use for a broad range of alien and invasive species research, policy and management applications and outputs (lower part of figure).

Tables 1-5 provide specific recommendations for their respective topics. Each table also includes details on:

- The **agents** best positioned to be responsible for implementation, which include the GBIF Secretariat, GBIF nodes, data publishers, the GBIF Governing Board (GB), the Task Group (TG), among others
- The **importance or priority** of the recommendation (High, Moderate, Low) and the suggested **timeline** for implementation of the recommendation (Short = one year, Medium = 2-3 years, Long = 3-5 years, ongoing)
- The suggested **approach or solution**
- The **difference that the recommendation will make** to the data fitness for use for A&IS research.

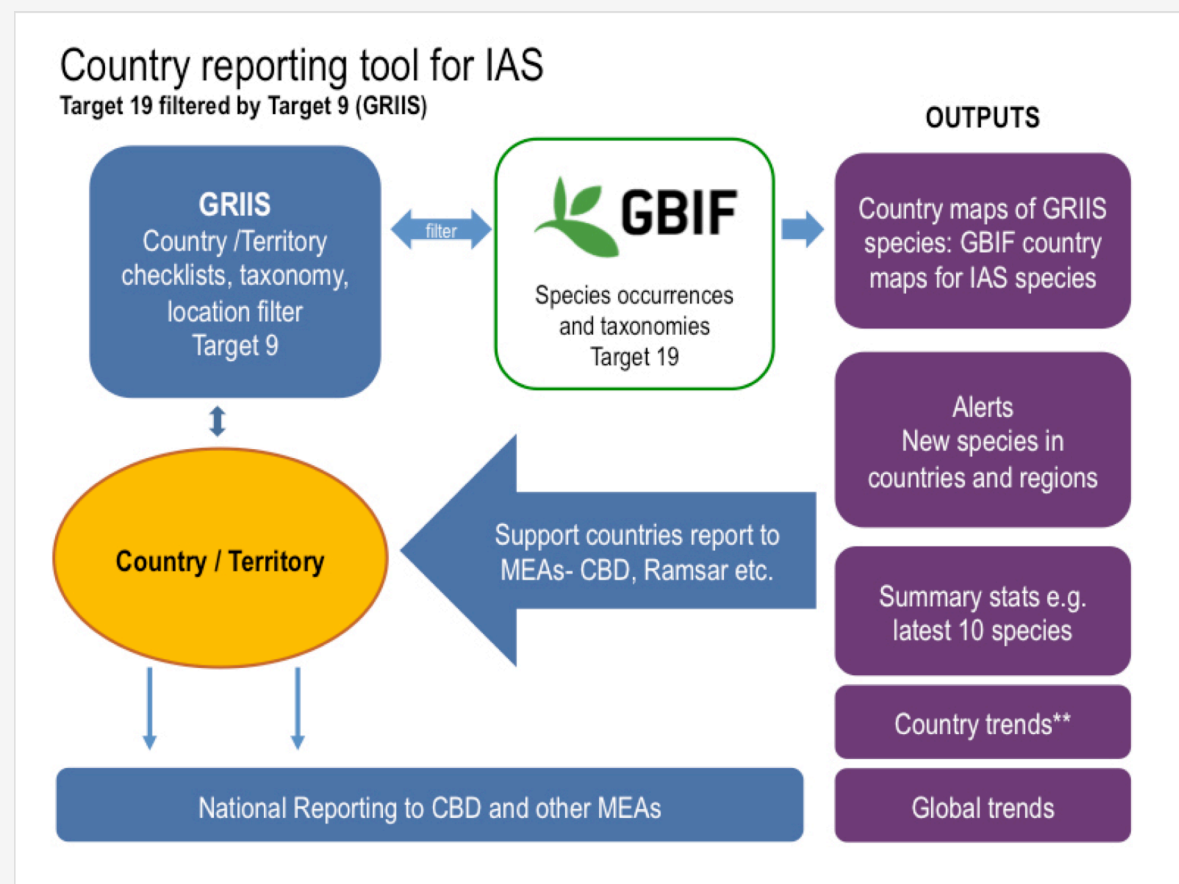
1. Strategic approaches and interventions for improving data fitness for use for A&IS

To most effectively improve data fitness for use for A&IS, we suggest an Alien and Invasive Species Data Strategy that translates this report's priority recommendations into tactics, actions and deliverables and creates feedback mechanisms for reviewing the success of implementation via expert or advisory groups. An important context for this strategy is to identify key geographic regions (continental, regional and national) with the largest data gaps and where improving GBIF's data coverage could generate the greatest gains for A&IS (*Table 1*).

Linking data published through GBIF to international initiatives relevant to A&IS, like the *CBD Strategic Plan for Biodiversity 2011-2020* and Aichi Target 9, and aligning work programs to assist in the delivery of policy priorities, particularly supporting countries with limited capacity, will not only benefit research (by leading to better data) but will also strengthen and broaden GBIF's contribution to biodiversity conservation more generally (*Box 1*). Consideration could be given to developing work packages or case studies that use priority A&IS to demonstrate the contribution of GBIF to these initiatives.

An important role for GBIF is to develop the existing infrastructure using A&IS relevant components of Darwin Core and the GBIF Integrated Publishing Toolkit (IPT), including the recommended changes to Darwin Core (*Appendix B.1*). GBIF could be effective at promoting Darwin Core new fields (terms), as well as the development of other standards for A&IS information, including type of introduction, native and alien distributions, area of origin, invasiveness and impact (*Appendix B.1*). Importantly, the research community is well equipped to provide the knowledge needed to underpin these developments and solutions, since the approach and structure for these areas has been a focus of extensive work in the field over the past two decades.

Box 1: Catalysing partnerships to support data fitness for use for alien and invasive species (A&IS) research and benefits for countries



A number of strategic opportunities exist to establish clearer policy-level links between data published through GBIF and international initiatives relevant to A&IS. The Global Register of Introduced and Invasive Species (GRIIS) is a product of the Global Invasive Alien Species Information Partnership (GIASIP) that provides verified checklists of A&IS at the country/territory level. Filtering GBIF-mediated data through GRIIS could prioritize the information that researchers and countries need to minimize the impacts of biological invasion. Filtering these checklists by taxonomy and location—facilitated by prescribed queries and other web services—can produce several outputs to help countries develop and report not only to the CBD but also on other Multilateral Environmental Agreements (MEAs).

For example, National Biodiversity Strategies and Action Plans (NBSAPs) are policy instruments developed by countries to provide information on plans and activities aimed at the implementation of the Strategic Plan for Biodiversity 2011-2020 and achievement of listed Aichi Biodiversity Targets. Countries that are Parties to the CBD are also encouraged to submit National Reports and provide information on their progress towards the implementation of the Strategic and the Aichi Targets. Aichi Target 9 encourages countries to identify invasive species and their pathways of introduction and spread (UNEP 2014), and prioritize them for management. Authoritative baseline data on the presence of alien and invasive species at the country and site level and their impacts on biodiversity and ecosystem services is therefore fundamental to the implementation of the Strategic Plan and Aichi Target 9.

GBIF could consider developing case studies or aligning work programmes that use priority A&IS, particularly in support of countries with limited capacity, to demonstrate its potential to contribute to these initiatives.

In addition, GBIF could take full advantage of the opportunity to utilize and incorporate data from the **Global Register of Introduced and Invasive Species** (GRIIS, <http://www.griis.org>) (IUCN SSC ISSG as part of GIASIP), which provides a key filter and prioritisation mechanism for GBIF. As an evidence-based and nationally verified list of species, we highly recommend its use for targeting and prioritizing the update, cleaning, completion and creation of relevant filters for this group of species data in GBIF. **Priority data include taxonomy, synonyms, common names, absence data, as well as native and introduced geographic ranges** (*Table 1*).

2. Improving existing data: quality, quantity and standards

Users of A&IS data, in particular researchers, regard **data quality and information on data quality** as essential (*Table 2*). Without this, researchers lose confidence in data provision platforms, seriously undermining the use and benefits of such facilities. Data quality is the joint responsibility of data publishers, holders and users, and we strongly encourage GBIF to continue to play an active role in improving and communicating data quality.

While relevant across all areas of research, this is particularly critical for research on A&IS, where errors may reduce the value and effectiveness of interventions to reduce the negative impacts of invasive species on biodiversity. For example, **accuracy and completeness of taxonomic information** is a core GBIF function and, given problems with synonyms and misidentifications of A&IS (McGeoch et al. 2012), an important focus for improving data quality and completeness. This applies not only to taxonomy but also to inaccurate location data, which the A&IS research community considers to be a significant challenge. Ideally, users could improved data using automated filters based on habitat/biome and flagged as suspect by a) using known range to identify outliers (from known range) and b) allowing the user community to flag records as potential outliers. Solutions like those implemented by the *Atlas of Living Australia* promote data quality, because this approach distinguishes high-quality data from less reliable data over time, even if publishers do not correct these records. Such communications appear particularly valuable and appropriate for A&IS.

It is also preferable that data on A&IS are made available as soon as possible through GBIF.org. The evidence available from GBIF shows a gap of 1-2 years between the collection and publication dates of observations. Such delays severely limit analyses of invasion dynamics and risk assessments, given the rapid pattern of spread for many alien taxa. GBIF's nodes, supported by the Secretariat, should engage with holders of data on the occurrence of invasive and alien species to persuade them of the importance of publishing and updating such datasets through GBIF.org as soon as possible following the observations, as this will provide researchers and policy makers with access to near real-time data on the spread of these species.

Darwin Core is the recommended and adopted standard for occurrence data (*Appendix B.1*). But it has shortcomings in its current form that hinder its value for A&IS data and research. Supporting necessary changes to Darwin Core fields and vocabularies is thus one key component of improving fitness of data for use in A&IS research. On its own however, DwC is probably inadequate to support the most essential A&IS information, and a range of other vocabularies and categorizations will need to be adopted and developed (*Table 2*) (e.g. standards for checklists and inventories, Guralnick et al. in review).

The unequivocal requirement from questionnaire respondents was that **observations must have a spatial resolution of 1km² or smaller**. Horizon scanning for potential new invasions requires the least precise data, but users require precise data for rapid response, niche modelling and impact assessment. Nevertheless, many data providers, particularly in Europe, obfuscate their data before publishing it on GBIF (Groom et al. 2016). In many cases the spatial resolution is reduced to 100 km². The reasons for this probably vary; for example, a conservation-based argument exists to protect the locations of endangered species from collection or persecution. By contrast, however, no scientific or conservation arguments justify obfuscating alien species observations.

The recommendations provided in *Table 2* below are divided into sections on taxonomy, data quality, data quantity and data standards.

3. Expanding information content

Two categories of information expansion were identified: 1) information relating directly or closely to occurrence data (alien and native range information, *Table 3*); and 2) a range of other information types key to A&IS research—and the broader management and policy user community—but currently not necessarily core business of GBIF (*Table 3*).

Enhancing occurrence data

The research community, supported by IUCN SSC and GEO BON, has identified occurrence and alien status (native versus alien) by geographic location (at species and record level) as two of the three essential variables for invasion monitoring (Latombe et al. 2016; <http://geobon.org/essential-biodiversity-variables/ebv-for-invasion-monitoring/>). GBIF is well positioned to be instrumental in supporting and enhancing the delivery of this information (see Appendix B.7 and B.10 for background on occurrence and range dynamics, alien and native range status and absence data).

Other data and information types useful for A&IS research

A number of other critical variables relevant to A&IS research and currently largely not supported by GBIF were identified. The recommended strategy for some of these is that GBIF partner with other information providers to support these broader A&IS needs rather than investing directly in facilitating access to such data (e.g. functional traits and pathways) (*Figure 2, Table 1*).

Some of these data types however are a priority for A&IS research, policy and management and we suggest a range of options and solutions for how GBIF may support information delivery using, for example, data filters, links, annotation or checklists (by geographic location) of species using categorical information from other sources (see *Appendix B.6*) and/or via strategic partnerships (*Table 3*). For example, ‘habitat’ includes physical and bioregional information associated with occurrence, and modelling where species can colonize and where to look from a detection perspective is critical for A&IS research, policy and management.

We see an exceptional and timely opportunity for GBIF to be a catalyst in drawing together disparate and existing data sets with key partners, leveraging diverse applications. For example, GIASIP or GRIIS could provide a platform for synthesis of extensive available data, which exist in many countries and regions, on mechanisms of introduction (pathways or

vectors, Ruiz et al. 2015) or the impact of species (Blackburn et al. 2014). Interaction between GBIF and other data sources (as outlined in *Box 1*) could be approached on an initial pilot scale; although many of these data sets are available and the types of analyses envisioned are not new terrain (but the focus of decades of research). By demonstrating their effectiveness and feasibility using a pilot, workflows could be optimized before scaling up.

One additional data type that did emerge as highly relevant and important to consider further is information on species interactions (see *Appendix B.8*). Species interactions profoundly influence the spread and impact of A&IS (*Appendix B.9*), with interactions between A&IS and biocontrol agents or parasites/hosts being prime examples. Currently GBIF does not hold such information in a way that is useful for A&IS research, nor are data publishers always providing these data. Although there are currently no widely available information sources for species interactions, enabling and encouraging the capture of such data would contribute to progress in this area. We outline three main areas where improvements may be made to improve data fitness for use for species interactions (*Appendix B.8*).

4. Functionality: expansion and refinement

A key GBIF stakeholder group is those users who use GBIF.org as a source of global information on species distributions (via occurrence records). They may not necessarily publish using GBIF-mediated data, but they are active users, often in the area of A&IS ecology and applied research. These users are unlikely to use the API to create visualizations of data, but they need easy access to summaries that quickly impart information related to biological invasions. The information they need is not just the specific details of occurrences and trends, but also information on biases in the data that facilitate a deeper understanding of what the data actually represent. Therefore, many of these recommendations relate to the metadata that surround A&IS, notably the provision of national checklists and alien species status (Table 4).

Currently, users have **four ways** to access GBIF-mediated data:

1. Browsing and searching at GBIF.org (note the new faceted search function)
2. Filter and download from GBIF.org (22 filters for occurrence data)
3. Request custom download from help desk. Exceptional cases, limited availability.
4. Machine access through API

Likewise, GBIF currently support **four types of datasets**:

1. **Metadata**-only datasets describe collections that are not digitally available.
2. **Checklists** are regional, geographic or thematic enumerations of taxa without the spatial and temporal data, **other types of checklists, such as taxonomically focused, special interest compilations, some may have occurrence records attached.**
3. **Individual occurrence data** have what-where-when information (taxonomy, collecting/observation date, locality information and coordinates).
4. **Sampling-event data** provides the information layer “wrapping” one or more occurrences with metadata details on sampling methodology and sampling efforts,

include lists and include abundance information in the form of species counts, biomass or other quantitative data. An additional table would be valuable listing the collecting events and their properties, and in the occurrences tables – event IDs, species counts = abundance information.

Function	Dataset types			
	Metadata	Checklists	Occurrences	Sampling-event
Browsing and searching at GBIF.org	+	+	+	-
	Better communicate value of GBIF for this purpose	Better communicate value of GBIF for this purpose	Expand attribute data, especially for alien-native status	Develop and promote use of A&IS data templates
Filter and download from GBIF.org	-	-	+	-
	Develop and promote use of A&IS data templates	Implement A&IS relevant filters	Enable extended filtering by geographic and governance layers	
Machine access through API	+	+	+	-
		Make more user friendly	Make more user friendly	

Figure 3. Summary of the data access functionality of GBIF.org as of October 2016, with a text summary of relevant expansions or refinements of functionality for A&IS research (see Table 4 for further detail). Note that the function for requesting custom downloads from the GBIF help desk is not included in this figure (while it may be available for each data type, it could be slow due to the Secretariat's other priority tasks). Plus and minus signs refer to currently existing and non-existing functionality, respectively, along with side a brief description of their value to A&IS research.

Usability of the website was a common theme in the responses from the survey and improving this will have many benefits to users and for the volume of traffic towards the GBIF portal. Even for competent informaticians, a rapid means to explore the data helps to spark ideas and encourage further usage. Many of these functionality improvements are targeted at GBIF itself, but data publishers also need to be aware that GBIF can only provide some functionality if the data are sufficiently rich to support this.

The value of alien species occurrence and sampling-event data can be significantly enhanced by enabling data extraction and providing relational data (such as information on vectors or pathways) for particular, highly relevant A&IS applications. Key filters identified thus far for GBIF-mediated occurrence and sampling-event data include land management governance boundaries (such as country, state/province and protected areas). Key attributes and/or derived data identified thus far include realm/environment, habitat, pathways and impact data (*Appendix B.10*). An alert function for priority taxa would be very valuable, for example, where anyone can "subscribe" to GBIF to obtain new record alerts for specific target taxa (see also *Box 1*). This would be very valuable both for research and managers, for example for use in risk assessment and invasion management. While capability may not

exist now in GBIF, it would not be a large investment for the research community to advise on how to do it, making sure the functionality delivers what we would like to see for research.

5. Communication and engagement

The viewpoint that GBIF could do more to improve its visibility as a provider of access to A&IS data was common across the communities consulted, and that it could actively advertise and engage with a range of relevant potential partners, related activities and data publishers (*Table 5*). The important role of GBIF to contribute to the formulation of data standards for A&IS was also highlighted, and to avoid duplication of effort and maximize complementarity by greater collaboration with other A&IS information platforms (e.g. United States Geological Survey (<https://www.usgs.gov>), Non-indigenous Aquatic Species (<https://nas.er.usgs.gov>), Global Invasive Species Database (<http://www.iucngisd.org/gisd>), GRIIS (<http://www.griis.org/>), Map of Life (<https://mol.org>) and Encyclopedia of Life (<http://eol.org>)).

GBIF has an established international data network and a network of national GBIF nodes that provide biodata services within the countries as well as training and guidance. Currently a significant proportion of data accessed through GBIF are observation data gathered through Citizen Science networks (e.g. Avian Knowledge Network) and output from surveys. All these data are available through the infrastructure provided by the GBIF Web-portal. Users can extract data from an integrated repository of data from a suite of data publishers. The A&IS research and the wider community are not the ‘traditional users’ of GBIF. Targeted communication and increased engagement, such as synergy with existing initiatives, developing dedicated A&IS data publisher and user networks are key to the involvement of this community.

Top priorities and key recommendations for improving the data fitness for use for alien and invasive species

Alien species occurrence includes *taxonomically verified species presence or absence records at a locality with a geographic co-ordinate, or in a prescribed area, management or geopolitical unit or site* (Latombe et al. 2016). Alien species occurrence information is the **single most important variable** necessary to support research, monitoring and management of A&IS. It is also one that requires in-situ collection from countries both with and without capacity to do so. Such data are the core of GBIF’s mandate, and GBIF is best positioned to provide open access to information of this nature. We therefore cannot emphasize more strongly how important GBIF is to this endeavour.

In conclusion, the following key themes emerged from the activities of the Task Group and are considered top priorities as part of an **Alien and Invasive Species Data Strategy** supported by GBIF. Several recommendations are relevant to other data users, but the availability and timeliness of these data are **especially critical for A&IS** because of the real-world consequences resulting from the negative impacts of biological invasions.

1. GBIF could increase its capacity as an essential hub for A&IS data. As an open data facility with an international mandate (see *Appendix B.2*), it is in a key position to advance data delivery and integration in support of A&IS research, policy and

management. As a neutral party, GBIF also has an essential role to play in supporting the Global Invasive Alien Species Information Partnership (GIASIP) to advance data delivery and their broad application.

2. An essential part of the strategy to improve fitness for use of A&IS data is to increase communication with national nodes to encourage urgent publication of data on A&IS to GBIF. For example, geographic coverage can be increased by having more partner countries and possibly targeted campaigns to increase species distribution data and increase resources available to do this.
3. An additional feature on the GBIF website is recommended to improve functionality for A&IS information and to increase its visibility, to show that the GBIF infrastructure is useful for this purpose and to attract data holders to publish data. This includes developing key partnerships to expand the range of A&IS relevant information accessible via GBIF, such as information on pathways/vectors.
4. GBIF's support for changes to Darwin Core and other necessary standards, and controlled vocabularies relevant to A&IS to enable functionality in GBIF to support A&IS research, is central to this strategy.
5. The following data and information improvements are essential to support fitness for use of A&IS data:
 - More geographically extensive and timely occurrence data that targets alien and invasive species
 - Geographic origin is included and data are explicit about taxa or records that are in captivity or cultivated versus those that are in the wild.
 - Explicit identification of the native and non-native ranges of A&IS at species and occurrence record levels.
 - Additional information on the mechanism of introduction (pathways or vectors), biome, and habitat for species.
 - Enhancements to identify outliers and spurious records that improve the overall quality and utility of A&IS data.

Finally, a range of opportunities exist for GBIF to continue to engage the research community to support its A&IS efforts, for example, to conduct gap analyses, articulate the necessary conceptual frameworks and ontologies to improve A&IS data fitness for use, to assist with evaluating the effectiveness of actions to implement the recommendations outlined here and to continue to promote the value of GBIF for this purpose.

Tables

Table 1. Strategic approaches and interventions

<i>Recommendation</i>	<i>Agent</i>	<i>Priority /Timeline</i>	<i>Approach</i>	<i>What difference will it make?</i>
1.1 Develop an Alien and Invasive Species Data Strategy to improve data fitness for use, including a logically structured model of information needs for A&IS and which of these GBIF may support	Secretariat	High Priority / Short-term	Conceptual development as presented in part in this report, as input into an Alien and Invasive Species Data Strategy.	Strategic, effective and efficient progress towards improving data fitness for use for A&IS
1.2 Increase the number of countries in the GBIF network	Secretariat, GIASIP	High Priority / Long-term	More countries to be encouraged to join GBIF, inter alia to benefit from the A&IS data available via GBIF	Better geographic coverage of species, more funds for GBIF, international collaboration on biological invasions facilitated, and countries aided to meet international obligations (e.g. under the CBD)
1.3 As an evidence-based and nationally verified list of species we recommend the use of GRIIS for targeting and prioritizing the update, cleaning, completion and creation of relevant filters for this group of species data in GBIF	Secretariat, Nodes, Global Invasive Alien Species Information Partnership (GIASIP)	High Priority / Short to medium term	Communicate strategy. Prioritize relevant investment and activity by focussing effort on species in this list. GIASIP to run a communication campaign, and provide resources. This is a strategic recommendation to render the list of tasks feasible by focussing efforts on a subset of taxa considered to be high priority A&IS.	Rapid progress on priority taxa to support research, policy and management, including Aichi Target 9's focus on high priority taxa (McGeoch et al. 2016).
1.4 Retain essential information and services that GBIF already provides in support of A&IS, especially taxonomic information, occurrence records, and web services	GBIF Board (GB)	High Priority / Short-term and on-going	Support Secretariat to sustain these services	Ensure sustainability of critical open source service provided by GBIF for this key threat to biodiversity (Groom et al. 2015, Appendix B.2)
1.5 Promote international standards for A&IS information and work with other data providers to achieve this (see Recommendation on DwC, Appendix B.1).	Secretariat, Nodes	High Priority / Short-term and on-going	Play a leadership role. Adopt a consensual approach, e.g. via an initiative similar to the recommendation of adopting the CBD Pathways Classification by the (UNEP 2014, Essl et al. 2015). Support necessary changes to Darwin Core fields and vocabularies, other controlled vocabularies, and relevant data and information standards.	Important changes in the standard of DwC to support A&IS data will be introduced and incorporated into future versions of Integrated Publishing Toolkit (IPT) for adequate publication of data on A&IS (Appendix B.1)

1.6 Ensure that the results of eDNA research are preserved without losing information	Secretariat, Genbank	High Priority / Short-term	See Appendix B.3. Include a strategy for eDNA data publication into Alien and Invasive Species Data Strategy .	This is part of ensuring that GBIF remain relevant and prepared for scientific and technical developments relevant to A&IS (Chown et al. 2015).
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Table 2. Improving existing data

<i>Recommendation</i>	<i>Agent</i>	<i>Priority and Timeline</i>	<i>Approach</i>	<i>What difference will it make?</i>
Taxonomy				
2.1 More detailed explanation of taxonomic uncertainties, including comprehensive information on synonyms	GBIF (as a taxonomic editor for A&IS)	High priority / Short-term	Refer to TDWG/GBIF Data Quality Interest Group. (http://www.tdwg.org). Mapping filters by geography to evaluate feasibility; open (crowdsource) opportunity for scoring or flagging data quality of suspect errors; also, encourage submission of potential corrections/suspected errors from papers/analyses.	Addresses the error rate and consistently improves quality in species x location records. By specifying the confidence in taxonomic accuracy users will be more inclined to use GBIF.
2.2 Improve the GBIF taxonomic backbone	Taxonomists, Catalogue of Life	Moderate priority / On-going	GBIF to provide a leadership role	Taxonomy is critical to all activities.
Data quality				
2.3 Improve mechanisms for identifying and correcting errors	Publishers, Nodes, Secretariat	High priority / On-going	Improve GBIF data-quality filters and feedback mechanisms to data publishers Nodes to provide a link and advice	Survey respondents considered this a high priority, so very important to ensure that end users continue to use and trust GBIF
2.4 Data publishers should not obfuscate records of alien and invasive species.	Publishers, Nodes, Secretariat	High priority / Short-term	If there is coding that identifies a species as alien, then it will be easy to filter and so ensure data on natives are not compromised. Once alien status is coded, it could be done immediately if there is political will	More accurate records so better for modelling
Increasing quantity of data accessible via GBIF				
2.5 Source data from novel sources and providers, in particular to increase taxonomic representivity	Secretariat, Nodes, GIASIP	High priority / Long-term	Expand communication of GBIF to a broader set of stakeholders (such as agricultural advisory services). Target data on pests and pathogens often housed in government or applied research institutes (e.g. Regional and National Plant Protection Organisations). Increase number of countries in GBIF network.	Better data on some of the most damaging alien species

2.6 Capture data that people have accumulated over their careers from archives and from Journals. Many researchers have needs to place their data somewhere. GBIF has role to play—mutual benefit.	Secretariat, Publishers, Researchers	High priority / Long-term	Develop and implement a strategy, reach out to community including scientists about to retire that have big datasets	More baseline data of invasions. Reducing wastage of research funding.
2.7 New data on occurrence of invasive and alien species should be published through GBIF.org as soon as possible after observations are recorded	Publishers, Nodes, Secretariat	Moderate priority / Ongoing	More frequent national updates, enable rapid publication of new records. Data workflows automated to minimize the lag time. Will involve direct engagement with relevant data holders by GBIF nodes and Secretariat	More responsive indicators. Near real-time publication through GBIF.org creates potential for 'live' monitoring of I & AS spread and early warning alerts
2.8 Taxonomists could be encouraged to publish checklists to GBIF	Nodes, Publishers	Moderate priority / Ongoing	Publication of a new flora or fauna should prompt submission of checklist data to GBIF	More authoritative lists of species for countries, information on native and alien status will be clearer
Data standards, controlled vocabularies and categorisation processes				
2.9 Adapt Darwin Core to address the needs of researchers and managers working on alien species	TDWG, Secretariat	High priority / Short-term	see Appendix B.1 (Discussion at TDWG Dec 2016; should be implemented by end of 2017 at latest)	Currently GBIF is not fit for purpose for work on alien species as it requires users to separately identify occurrence records and their alien/native status
2.10 Design and implement new standards for information on dispersal vectors both at the species-level and geographic-level that is explicit about how these have changed through time	GIASIP, Secretariat	High priority / Medium- term	see Appendix B.4	Needed to comply with spirit of Aichi Target 9, will help pathway management lessons be transferred
2.11 Need standard protocols for defining native ranges	Secretariat, Researchers (GEO BON)	High priority / Medium- term	See Appendix B.5. Research needed and community engaged. Existing protocols need to be reviewed. A consideration of how species will respond to global change.	This is fundamental to invasion science, and will resolve some uncertainty.
2.12 Design and implement new standards for information on species- and geographic-level attributes relevant to biological invasions	TDWG, GRIIS, GIASIP, CABI	High priority / Medium- term	See Appendix B.6. Coding for traits, use of pre-existing standards Coding for status of populations (e.g. impact mechanisms and levels, Hawkins <i>et al.</i> 2015)	For example, facilitate comparisons between invasive species for use in risk analyses

Other				
2.13 Provide more links to references and related information sources	Publishers	Low priority / Medium- term	Data publishers to use permanent identifiers	Improve confidence in the quality of the data, and their ability to track data provenance
2.14 Encourage data collectors to record resolution at the appropriate scale for the organism	Publishers, Nodes, Secretariat	Low priority / On-going	Produce training material, develop and promote the use of relevant A&IS data templates.	Better data

Table 3. Expanding information content

<i>Recommendation</i>	<i>Agent</i>	<i>Priority and Timeline</i>	<i>Approach</i>	<i>What difference will it make?</i>
Alien and native range information				
3.1 Identify data layer source(s) that classify species x location as native, non-native, cryptogenic.	Secretariat, Nodes	High priority / Short-term	Develop partnerships that build on one of several existing data resources for vectors, including GIASIP. Working group of partner organizations, to establish standard approach, framework, and operation; possibly begin by pilot project before scaling up. Review and use classification framework that is consistent with existing (e.g., IUCN, CBD, etc.). Appendix B.5	Tractability of invasion dynamics and spread, by geographic region and taxa. Provides core data for research and for user countries and legal frameworks.
3.2 Record level: Distinguish current from historical distribution	Secretariat, Publishers	High priority / Short-term	Tag records as native, non-native or unknown. Absence records are important here. Enable and promote functionality to achieve this. Appendix B.5, 7,10.	Critical to research, policy and management of biological invasions, this information was the most frequently mentioned priority in the survey
3.3 Species level: Flagging of provenance of species, inclusion of native range/ alien range	Secretariat	High priority / Short-term	Appendix B.5, 6,10	This information is critical to research, policy and management of biological invasions and was the most frequently mentioned priority in the data fitness for use A&IS survey
3.4 Record level: Distinguish whether a record is within or outside captivity or cultivation.	Secretariat	High priority / Short-term	Records could be tagged as within captivity or cultivation. Appendix B.6	This information is critical to research, policy and management of biological invasions, especially for SDMs. This is the set on which future invasion may come from, and the data that can indicate when invasions have not happened despite some opportunity for them.

Other forms of data relevant to A&IS				
3.5 Habitat characteristics	Secretariat	High priority / Short-term	Add physical characteristics such as elevation/depth, temp, salinity, substrate type to collection/occurrence records; same may apply to biome (esp. since this changes over time per location). GBIF could include these in occurrence records as standard in Darwin Core. Develop and promote use of data templates.	Improves estimation of realized niche and particular habitat distribution—both to characterize occurrence, impact, and inform detection/management
3.6 Vector data	Secretariat, GIASIP	High priority / Short-term	See Appendix B.4. Working group of partner organizations, to establish standard approach, framework, and operation; possibly begin by pilot project before scaling up. Vector designations at fine level require standardization of existing schemes (which can be readily achieved by the research community). Develop partnerships that build on one of several existing data resources for vectors including GIASIP.	Associating A&IS species and records with vector information will contribute significantly to better understanding variation in habitat use and dispersal mechanisms.
3.7 Include survey/sampling effort estimates	Publishers	Moderate priority / Short-term	Build into sampling-event data / survey data strategy	Essential to enable abundance and impact inferences as well as reliability of apparent absence information (Appendix B.10).
3.8 Species interactions (host associations, biocontrol agents)	Secretariat, GIASIP, Researchers	Moderate priority / Long-term	See Appendix B.7 on Interactions. Working group of partner organizations, to establish standard approach, framework, and operation; possibly begin by pilot project before scaling up.	Such data will support research to understand biological invasions and their impacts (e.g. Ruiz et al. 1999).
3.9 Impact data	Secretariat	Moderate priority / Short-term	Develop partnerships that build on existing data resources for impacts, see Blackburn et al. 2014, Hawkins et al. 2015. Appendix B.9	Enables tracking of A&IS for early alerts and also to prioritize data collection campaigns in order to predict/understand invasion dynamics/impacts of target species. Serves diverse end-users in science, management, and policy. These are the species that serve as metrics for ecosystem management (CBD) and also focal species for biosecurity.
3.10 Functional traits, physiology, cultivars	Secretariat	Low priority / Long-term	Identify and develop partnerships with relevant data holders. Develop partnerships that build on existing / emerging data resources for traits.	Critical for analysing and predicting performance of A&IS, e.g. what makes some taxa have more "success" and impact. Informs policy prioritization to prevent/manage invasions and prediction of species response to forcing functions like climate change.

3.11 Abundance data	GBIF catalyzes with partner orgs, Nodes	Low priority / Long-term	Promote abundance measures as part of "sampling-event data" strategy, using several model systems of high impact "priority" species (Appendix B.11); this become focus of collaborative working group; good target for pilot to demonstrate and promote	These data are needed to better understand the impact of biological invasions and create better models of invasion.
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Table 4. Expanding and refining functionality

<i>Recommendation</i>	<i>Agent</i>	<i>Priority and Timeline</i>	<i>Approach</i>	<i>What difference will it make?</i>
4.1 Dynamic visualizations of alien species data trends and "gaps", by region, taxa, and groups	Secretariat	High priority / Short-term	Visualizations. It would be interesting to do this by comparison with "native" species. E.g. Express accumulation of records for species in GRIIS, temporal trends in records accumulated per species and per country, trends in number of species and number of 'invasive' species listed on GRIIS	Encouraging data publication Rapid assessment of risk and status Help to prioritize the filling of key data gaps
4.2 Enable generation of maps of first and last record generated for each country/TDWG region from data on GBIF	Secretariat	Moderate priority / Short-term	Pre-generated maps created at monthly intervals	A rapid overview of data that indicates data coverage and introduction. It will become easy for users to assess the data quality. A motivating tool to encourage data provision.
4.3 Make the data easier to use, easier to extract and contribute information to (Plugin for QGIS, tool to make it easier to construct api queries) User friendly and simple access that does not require IT experts	Secretariat	High priority / Medium- term	Training sessions at relevant conferences. More user-friendly interface and/or guidance online on how to do it.	GBIF would be accessible to a much broader user base.
4.4 Assess the new GBIF website in terms of its data access and useability	Secretariat (possibly through a new Working Group)	High priority / Medium- term	Set up a working group and consultation process specifically targeted to assess the usability of the website. This must include casual users and those without experience or proficiency with APIs, GIS.	Make GBIF.org more user-friendly and encourage return visits. A common comment received was that the previous GBIF website was not intuitive and hard to navigate even for experts.
4.5 Checklists derived from occurrences made available for each country, that include all taxonomic groups with the native or introduced status of each taxon	Publishers, Secretariat, GIASIP	High priority / Medium- term	Updates of the respective GBIF.org pages	This would provide summary statistics for alien species in each country. It would give information on the species present in the trading partners of a country, which would be useful for watch lists and horizon scanning.

4.6 Provide key links from species pages to related and supplementary information sources on A&IS	Secretariat, GIASIP & External portals	Moderate priority / Long-term	External links to resources for A&IS impact assessments to evaluate space and time-dependent indicators of invasion effects (Appendix B.9).	Improved awareness of which species are invasive and the impacts caused.
4.7 Alert systems for particular species of interest to individuals and organizations by region, e.g. using GRIIS as a filter. Able to identify outliers that could indicate the first spread of an organism.	Secretariat or, ideally, external portals using GBIF API	Moderate priority / Long-term	Alerts	Better surveillance and rapid response tools for invasive organisms. Better prioritization and more rapid updating of prohibited lists. (Appendix B.11) Could also facilitate targeted “detection campaigns”. Improved validation of outlying observations.
4.8 More and more suitable filters when searching for observations—particularly for searches within a user defined polygon, realm/environment, habitat, pathways, impact data, land use and by the native status	Secretariat to provide the infrastructure and providers and publishers to provide more and richer data	High priority / Medium- term	Spatial filters for data types other than occurrences, such as custom biogeographic or protected area filters, with plug-in for QGIS. Use the field 'Origin' in DwC as a filter. Filter by list and by the shape file	Increases the usefulness of occurrence data, such as assessing invasion risk for particular protected areas. Countries trying to minimize invasions need to know how many species per realm over time for example, the relative extent of invasion in different ecosystems. Biosecurity management. Easier to join data with other databases on invasive species such as World Database of Protected Areas, World Register of Introduced Marine Species
4.9 Critical annotation of data records, e.g. flag outliers, corrected records (see also <i>Table 3.4</i>)	Secretariat Publishers	High priority / Short-term	Enable users to report errors as annotations. Some annotations might be automated. Secretariat to provide a mechanism, Publishers, an annotation process	An enrichment of the data. Allow rapid feedback to publishers. Reducing the duplication of effort when cleaning data.
4.10 Inclusion of key location types and codes that are relevant to the invasive species issue such as islands, protected areas and other recognised areas of high biodiversity value such as Important Plant Areas, Important Bird Areas etc.	Secretariat, external partners	High priority / Short-term	Spatial layers. Allow users to map biogeographic regions over the data (e.g. MEOW ecoregions).	Rapid assessment of the potential impact of invasion. Provide functionality to users with a poor IT proficiency to use the data. A quick overview showing the bioclimatic envelope that the organism exists in.
4.11 GBIF to provide usage statistics at a data publisher level	Secretariat	Low priority / Short-term	Yearly download data for each dataset. Clear and trackable statistics that can be used in the annual report of an organization.	This will encourage data publishers to monitor the usage of their data and promote good stewardship of their data.

4.12 Facilitate expanded web services (e.g. filters) focused on the needs of the A&IS stakeholder community	Secretariat	High priority / Medium- term		Currently no A&IS specific filters
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Table 5. Communicating with and engaging the A&IS community

<i>Recommendation</i>	<i>Agent</i>	<i>Priority and Timeline</i>	<i>Approach</i>	<i>What difference will it make?</i>
5.1 Establish/flag a specific A&IS entry route (or specific page/website) into the Facility	Secretariat	High priority / Short-term	Website pages that channel users and/or profile what GBIF can do and is planning to do for A&IS research, policy and management	Greater participation by the A&IS research community, both as users and as data publishers
5.2 Improve the visibility and credibility of the site for A&IS information	Secretariat	High priority / Medium-term	Promote use through training sessions, guidance etc.	Involve a much broader community of researchers in GBIF
5.3 Engage with and encourage a range of information providers/publishers including A&IS expert networks, researchers, relevant journals and thematic information providers to contribute data to GBIF	Secretariat, Nodes	Moderate priority / Medium-term	Increased engagement and collaboration with a range of A&IS data publishers	A richer, better linked system
5.4 Incentivize data publishers (Profiling data publishers ranging from researchers to citizen scientists)	Secretariat	Moderate priority / Medium-term	Profiling data publishers/ small grants/	Greater participation by the A&IS data publishers
5.5 Increased synergy with existing A&IS related initiatives at the global, regional and national level (to avoid duplication of effort)	Secretariat, GIASIP, Nodes	Moderate priority / Medium-term	Increased engagement and collaboration with a range of A&IS data publishers	A richer, better linked system

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