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Capacity of United States Federal Government and its partners to rapidly and accurately report the identity (taxonomy) of non-native organisms intercepted in early detection programs

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Abstract
Invasive Species Early Detection Rapid Response (EDRR) depends on accurate and rapid identifications. National U.S. EDRR implementation requires an integrated identification system with a sustainable taxonomic resource, comprising expertise, identification tools, collections, laboratories and databases - operating across and between federal and State agencies. Process chains between interception and suitable level of diagnostic expertise need to be rapid, simple and well-understood. Taxonomic expertise is being lost and needs to be revived, to ensure timely authoritative identifications for difficult species and revisionary work targeted at priority problem groups. Citizen science needs to be strengthened and appropriate identification tools and management systems developed. Coverage of DNA barcode libraries and other molecular resources needs to increase. An integrated database of all U.S. biota and known invasive species needs completion.

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Early Detection and Rapid Response; EDRR; invasive species; taxonomy; diagnostics; pests; biosecurity; identification

INTRODUCTION

Importance of IAS

Invasive species pose a growing threat to the United States (U.S.), environmentally, economically, infrastructurally, to health and to biosecurity (Meyerson and Reaser 2003; Simberloff et al. 2013; Bradshaw et al. 2016; Gallardo et al. 2016; ISAC 2016; overview paper, this volume). The estimated cost is nearly $120 billion annually (Pimentel et al. 2005), and is expected to increase (Epanchin-Niell 2017). Invasive species already in the U.S. pose risks to other countries (Paini et al. 2016), which may impact U.S. trade.
Biological invasions are increasing rapidly (Hulme 2009; Saccaggi et al. 2016) with growing global travel, trade network connectivity and pathway complexity (US Congress, 1993; Work et al. 2005; Stack et al. 2006; Essl et al. 2015; Chapman et al. 2017).

Minimising invasive species impacts requires early knowledge of their presence, rapid risk assessment, and timely and effective management responses. Early Detection and Rapid Response (EDRR), already implemented subnationally in many parts of the U.S., delivers this.

The National Invasive Species Council (NISC), established by Executive Order (E.O.) 13112 and updated with E.O. 13751, has set out in its Management Plan (NISC 2016) assessments necessary to inform the development of a national EDRR program (United States Department of the Interior 2016). This paper is one of these: *Action 5.1.4. The capacity of the Federal government and its partners to rapidly and accurately report the identity (taxonomy) of non-native organisms intercepted in early detection programs*. In 2016 NISC sent a data call to federal agencies to discover current activities and capacity for EDRR.

Currently the taxonomic element of U.S. invasive species management appears to be faltering, operating at less than optimal efficiency. A complex set of federal, state and other entities provide or have the potential to provide taxonomic support to identification of invasive species and creation of identification tools, but discovering the identities and capacity of these entities is challenging. Many are collaborating at some level, but there are few clear identification process chains (see below) and some correspondents had problems locating these. Developing a sustainable taxonomic/identification system to support a wider EDRR programme requires simplification, streamlining and greater collaboration, clarity on available capacity, and flexibility to adapt to changing pressures. Above all it needs to deliver rapid responses to identification needs. Recommendations to achieve this are made below, developed in part from statements from correspondents and submissions to the National Invasive Species Council (NISC) Data call.

The Importance of Identification and Taxonomy for Invasive Species Management

The importance of taxonomic support for invasive species identification has been emphasised globally (Smith et al. 2008; Pyšek et al. 2013) and nationally (Chitwood et al. 2008; Diaz-Soltero and Rossman 2011). A general concern, also raised by federal agencies and individuals contacted in this study, is the diminishing availability of taxonomic expertise, arising from a decreasing number of scientists and changing priorities of laboratories (Stack et al. 2006).
The importance of correct identification rapidly delivered cannot be overstated. The provision of a (scientific) name for an organism suspected to be invasive allows:

- clarity whether the organism is likely to be non-native;
- access to biological, ecological, pathway, and management information;
- finding any county, state or federal actions prescribed;
- unequivocal communication between stakeholders.

Rapidity is important. In 2002 the 'Rasberry crazy ant' was reported from Houston, Texas. This proved to be very difficult to identify, but even getting specimens to taxonomists sufficiently expert in the group took too long. Identification was not confirmed until 2012 (Gotzek et al. 2012), by which time the species had spread considerably and caused massive damage.

Capacity Issues

National EDRR will necessarily use modalities already in place. The more efficient they are, the more applicable to EDRR implementation; current activities inevitably involve state and other resources, particularly for identification skills. Although this paper focuses on federal capacity it consequently includes some state activities and resources.

Key Scenarios Requiring Identifications

The circumstances in which a potential invasive species is detected in EDRR have strong implications for the problems faced in its identification and the personnel engaged in the

Identification Process Chain, and thus capacity requirements. Two non-exclusive axes can be used to explore this (Fig. 1).

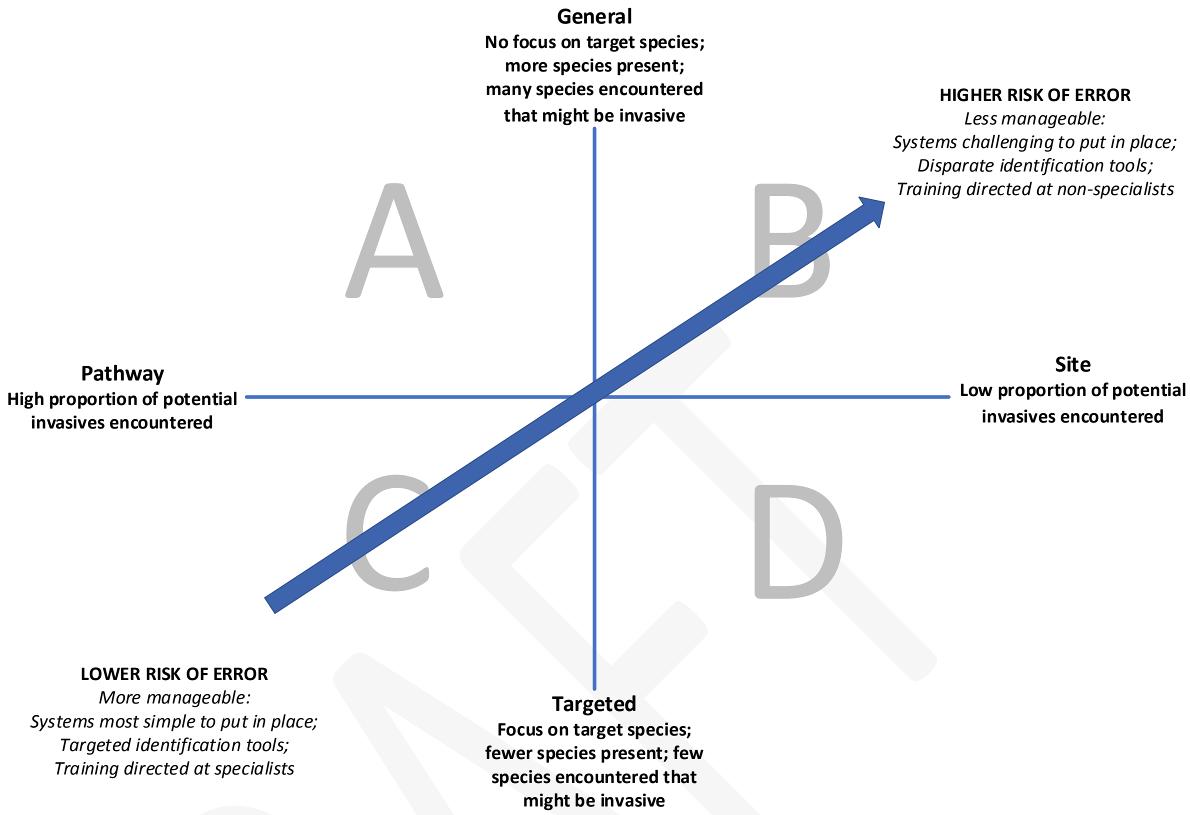

Fig. 1. Identification scenarios. The greatest management challenges and highest risk of error are in the top right, the most sustainable management possibilities in the bottom left. The background letters are for reference in the text.

Axis 1: Targeted cf. General inspections. Targeted inspections and monitoring activities focus on one or few key species (e.g. Asian carp detection, Asian Hornet in the United Kingdom [GOV.UK 2017]). General inspections such as BioBlitzes (Silvertown 2009, DITOs Consortium 2017) will expose the inspection team to a very large number of species which may or may not be actually or potentially invasive.

Axis 2: Pathway cf. Site inspections. Pathway inspections screen for actual or potential invasives in the context of a pathway (e.g. solid wood packaging at Ports of Entry [PoE], trailered boats through State Line inspections) and site inspections where invasive species might be detected within the environment (e.g. National Parks, agricultural extension).

The two axes operate together, for example targeted inspections are most effectively carried out as a result of risk assessments that highlight pathways (European Environment Agency 2010).

Targeted and Pathway inspections (Fig. 1 quadrants C-A)
Both Targeted and Pathway inspections are most likely to feature a limited number of target species (potentially much higher in pathways), a relatively high proportion of target to non-target (non-invasive species that might be confused with invasives) observations; many repeat observations; a geographically fixed base; long-term staff or citizen science engagement. These allow focused identification tools; staff training and expertise build-up in the use of sampling

equipment and identification tools; sensitisation to target species; strong, formalised and short Identification Process Chains (IPC - see below) with high potential for rapid response; and minimised risk of error. For example U.S. Fish & Wildlife Service (USFWS) uses eDNA to detect invasive carp in the Great Lakes (Jerde et al. 2013; Mahon et al. 2013); U.S. Geological Survey (USGS) has collaboratively developed a field method to detect rapid 'Ohi'a death fungus in Hawaiian Ohi'a trees (Atkinson et al. 2017) (both of these would be quadrant C).

PoE Pathway inspections (Fig. 1 quadrants A-C) feature trained staff and rapid IPCs, either to local Plant Inspection Stations (USDA 2017a), or through USDA's Animal and Plant Health Inspection Service (APHIS) National Identification Service (USDA - APHIS 2015), Centers for Disease Control and Prevention (CDC) (CDC 2013), or USFWS (USFWS Office of Law Enforcement 2017). U.S. Customs and Border Protection (CBP) Agriculture Specialists (CBPAS) are trained to identify pests and diseases but their preliminary identification has to be confirmed by a USDA entomologist or plant pathologist. APHIS has a rapid (24 hour) identification system in place (at least where taxon specialists are available). CBPAS and others at PoE are supported by specialist identification tools (USFWS 2010; USDA - APHIS 2017a). State Line Pathway inspections (Fig. 1 quadrant A) are particularly important for States with significant agricultural industries such as California and Florida, where inspection agents can send interceptions or photographs to taxonomists in a formal system (CDFA 2018a). A special case is watercraft inspections, where detection of biological material alone may be sufficient to require decontamination; individual organisms are not identified.

General and Site Inspections (Fig. 1 quadrant B)
In contrast, these (where a Site inspection is not also Targeted – quadrant D) are likely to feature an unknown and potentially large number of target species, a relatively low proportion of target to non-target observations; few repeat observations; intermittent inspections without a fixed base for staff; short-term observer engagement, with involvement of amateur and ad-hoc observations. These lead to employment of many identification tools of mixed quality; fewer opportunities for staff training and building expertise; weak or ad-hoc IPCs; higher risk of not identifying potential invasives at low density. Rapidity is more challenging.

These pose the most challenging model for capacity. Often they are handled regionally, with variable integration between regions (e.g. USDA's National Institute of Food and Agriculture [NIFA]'s Crop Protection and Pest Management Program (CPPM) (USDA – NIFA undated), USFWS regions), or between sites (e.g. DOD lands, National Park Service [NPS]). DOD manages invasive species under local Integrated Natural Resources Management Plans (INRMP) liaising with the USFWS, but with no national coordination. The number of possible species poses a problem. Allen et al. (2009) report 3,756 different non-native plants in U.S. National Parks with a maximum of 483 from one park, and more than 120 National Parks contain 50 or more non-native species (Stohlgren et al. 2013). There is a risk that supplying enough information locally to facilitate identification might overwhelm identifiers with too many resources.

Agriculture is perhaps better served than environment, with the APHIS Cooperative Agricultural Pest Survey (CAPS) Program (USDA – NIFA undated), which carries out national and state surveys targeted at specific exotic plant pests, diseases, and weeds identified as threats to U.S. agriculture and/or the environment, much of which operates at state level through the Cooperative Extension System (CES).

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BUILDING A SUSTAINABLE TAXONOMIC RESOURCE TO SUPPORT EDRR

A sustainable taxonomic resource includes capacity both of people and the resources they use (Table 1). Crucially, all elements must be present and available; lack of taxonomists removes the most authoritative layer, and precludes identification of many interceptions, while loss of citizen science input may make general site surveys impossible. Taxonomists and other identifiers require collections and identification tools, and all stakeholders must have access to the same lists of names. Not only must the elements be present, but the personnel (and those detecting possible invasive species and seeking identifications) must be efficiently connected by an Identification Process Chain (see below). Different aspects of a sustainable taxonomic resource may be preeminent in EDRR activities in different quadrants of Fig. 1, but the whole structure is required for any of it to be fully operational. For such a system to function there has to be some oversight, or at least a central resource or portal where information and contacts can be shared. This should be a facet of whatever coordination mechanism is put in place for national EDRR.

ACTORS	ROLES				KEY RESOURCES USED				
	Research – establishing species concepts; correct names to use	Generating identification tools	Identifications	Compiling authoritative lists of names	Collections	Laboratories, including DNA	Lists of names	Identification tools	Other Literature resources
		Table 2			Table 5 Table 7		Table 8	Table 6 Table 7	
Taxonomists (Table 3)	*	**	*	**	*	*	*	*	*
Expert identifiers (Table 3)		*	*		*	*	*	*	*
Database managers				*			*		*
Citizen scientists (Table 4)			*				*	*	*
Other interception and survey personnel			*				*	*	*

Table 1. Actors and key resources in a sustainable taxonomic framework. An effective EDRR will require all actors and resources, appropriately targeted.

This taxonomic resource capacity cannot exist in isolation, and will operate in response to requirements from its users. Federal bodies and users of invasive species identification expertise or tools should therefore consider their requirements and how they are met, and ask themselves:

1. Is the current supply expertise supply sufficient and subject to management? (Any expertise based on retired specialists or being provided on an ad hoc basis is not within management capacity of the body.)
2. Are high-risk groups of organisms of key importance covered taxonomically?

3. Where will expertise and supply of identification tools come from in five years' time? (Taxonomists take time to train and recruit, and a succession plan is needed to ensure that at least high-priority groups are covered).

Identification Process Chains

In the context of EDRR three stages can be considered: observation (interception, screening, collection, etc.), identification, and receipt of identification by the management authority; the links between these may be termed the 'Identification Process Chain' (IPC) (Fig. 2).

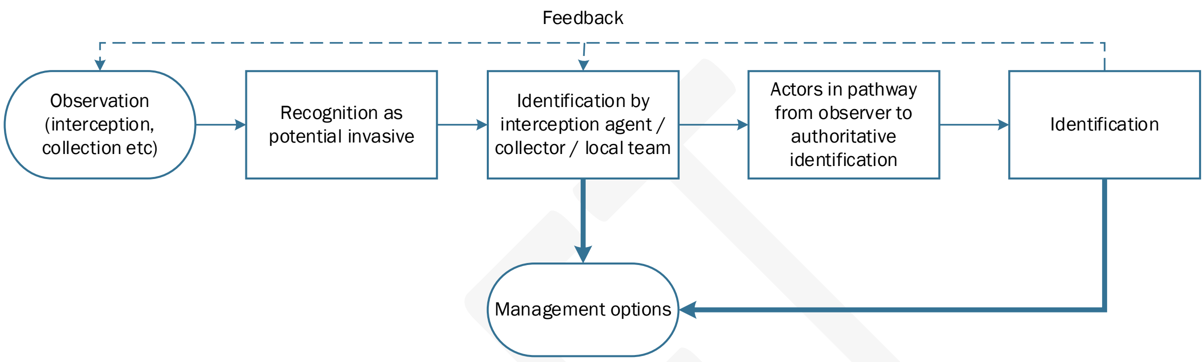

Fig. 2. Identification Process Chain (IPCs) from observation to identification and from identification to management. Feedback may assist future identifications.

The IPC should be rapid and effective (Stack et al. 2006; NISC Secretariat 2016a), and managed so that both specimens and necessary information are transmitted along it and all individuals know procedures to follow and the priority of the submission. The more complex the chain the longer the identification process (Smith et al. 2008), the greater the chance for miscommunication, and the less it is fit for EDRR.

IPCs differ between agencies and even different regions or staff within a single agency, and they may not be fixed or widely understood. Almost every agency responding to the NISC data call, and many individuals contacted, called for stronger linkages between those intercepting possible invasives and sources of taxonomic expertise (NISC Secretariat 2016a).

Members of established networks, such as the National Plant Diagnostic Network (NPDN) (Stack et al. 2006; NPDN 2017), National Animal Health Laboratory Network (NAHLN) (USDA - APHIS 2017b), the Federal Interagency Committee for the Management of Noxious and Exotic weeds (FICMNEW) (FICMNEW 2017) and the Wildlife Health Information Sharing Partnership event reporting system (WHISPers) may through their interactions facilitate a sample reaching the appropriate expertise. This potential may not yet be fully realised.

Collaboration is an important component of EDRR (NISC Secretariat 2016a), and may facilitate locating expertise. Collaboration between CPB, USDA, CDC and USFWS on PoE is a very strong example. Department of Defense (DOD) and the USFWS work together on DOD lands, and the Great Lakes Restoration Initiative involves collaboration between USFWS, Environmental Protection Agency (EPA) and USGS.

Federal agencies operating without a national framework to engage with taxonomic capacity may rely more on local expertise. When this is insufficient, individuals may have difficulty locating the appropriate resource or finding an established IPC appropriate to the species in question. Not all IPCs are open to all agencies.

There are few online expert directories. USDA provides suggestions on which labs to submit identification requests (USDA - APHIS 2017c). The Aquatic Nuisance Species Task Force maintains an Experts Database by State (USFWS undated) including taxonomists. The page also carries links to the European DAISIE expert search (DAISIE 2008) and to U.S. systems that no longer exist: the National Oceanic and Atmospheric Administration (NOAA) "Taxonomic Cadre" and the National Biological Information Infrastructure (NBII) "Taxonomic Resources and Expertise Directory"; NBII has been off-line since 2012, at least partially because of budget cuts (USGS 2011), although some elements were later covered by BISON (Biodiversity Information Serving Our Nation). Some professional societies maintain membership lists (e.g. ASPT 2012), but with no guarantee of completeness or expertise. USDA has a web-based search tool for connecting researchers with peers, although it does not search for taxonomists (USDA 2017b).

The rapidity of response in an IPC can be increased by local identification capacity in any of the quadrants in Fig. 1, facilitating finding the appropriate specialist. An example is Preclearance Inspections conducted in some countries exporting to the U.S., performed under direct supervision of qualified APHIS personnel (USDA undated). USDA preclearance manuals (USDA 2011, 2012a, b, 2013, 2014a, b, 2015) mostly do not include identification aids, although USDA (2011) shows images of bulbs attacked by pests or pathogens, and USDA (2012a) has rather crude line drawings and some photographs not indicating diagnostic features. Shippers are required to identify plants (and are provided with lists of names), but there is no guidance on tools or taxonomic standards that should be used. Taxonomic skills and resources in other countries may be absent, so identifications of imports to the U.S. may not be possible or employ the same taxonomic concepts and names as used in the U.S. While there is no guarantee that the identification given matches U.S. concepts, this is subject to checking at APHIS Plant Inspection Stations (USDA 2007) and may speed the process.

Failure to have an authoritative Identification Process Chain can have serious consequences, as with the recent case of *Drosophila suzukii*, where following an incomplete identification from local experts a farm advisor used a web search engine to locate an expert. Unfortunately this was not a taxonomist and the identification was incorrect, hindering response (Hauser et al. 2009; Hauser 2011).

Increasingly image based systems allow rapid submission and transfer, so the specialist can see the specimens in a shorter time, although images are more effective for some organisms than others (G. Miller, Chamorro *pers comm.*).

Expertise and Infrastructure

Sources of identification

Identification at the point of interception may simply recognise there is a potential invasive present and require authoritative review, or may provide a preliminary or final identification. Local capacity to deliver this is built on informal or formal training and appropriate identification tools.

If identification is not possible locally to the appropriate confidence level greater taxonomic expertise may be sought in state and federal bodies, such as laboratories maintained by the

USDA Agricultural Research Service (ARS), the CDC and the Smithsonian Institution (SI), and many state universities, although this may lengthen the IPC.

Professional taxonomic expertise is required for the most authoritative identifications, to develop and maintain identification tools and to manage the contents of taxonomic databases. Availability of such expertise in a timely manner needs to be planned and managed (Smith et al. 2008). Federal bodies cannot supply expertise to manage all current requirements for invasive species management; a national EDRR programme provides an opportunity to review and build capacity efficiently across federal and state agencies, universities, and private companies.

IPC – Aspects Hindering Rapid Identification	**Actions to increase rapidity**
Experts difficult to locate	1. NISC should establish EDRR Coordination Mechanism ('EDRRCM'), perhaps by expanding role of NISC Secretariat 2. EDRRCCM to work with federal and state agencies to develop and enhance IPCs for EDRR procedure: a. Create and use lists of experts b. Encourage MOUs between stakeholders including experts to: i. Develop formal networks and IPCs ii. Ensure timely availability of experts c. Engage established networks / IPCs to participate in national EDRR 3. Established networks to facilitate IPCs by improving linkages
Experts working for unconnected organisations	1. EDRRCM to develop mechanism to assist partnerships 2. Individual agencies and organisations to increase collaboration, with formal MOUs where possible 3. Agencies managing IPCs to consider opening them to other agencies where appropriate and necessary to facilitate identifications in EDRR
Experts in distant localities	1. Agencies managing site inspections to increase efficacy of expertise on site a. Use professional identifiers at fixed sites b. Make use of trained citizen scientists c. Increase use of appropriate identification tools d. Work with established networks / IPCs 2. Improve rapidity of IPCs a. Site managers to establish preliminary identifications where possible to facilitate transmission to relevant expert through IPC b. Users send images where appropriate c. EDRRCM to recommend targets for rapidity of transmission d. EDRRCM to work with agencies to develop and emplace standard reporting and specimen transmission system

Table 2. Identification Process Chains: Recommendations

Current trends may indicate projected needs. USDA Systematic Entomology Lab (SEL) identification requests from PoE (each of which might include multiple specimens and species) rose from 9,624 in 2004 to 17,755 in 2010, the 'urgent' requests from 3,572 to 8,469 in the same period (Solis *pers com.*); in 2016 SEL received 30,000 specimens for identification (G. Miller *pers com.*). Each day CPB intercepts around 470 plant pests and diseases (Harringer 2016; NISC Secretariat 2016a) and seizes around 4,548 prohibited plant materials and animal products (NISC Secretariat 2016a). Work et al. (2005) suggested that port interceptions were not finding all species, suggesting an insufficient inspection rate and potentially higher identification requirements. An enhanced EDRR system will increase calls for identifications.

Expertise Available
Many correspondents stated that obtaining identifications was very time-consuming or impossible. Lack of experts appears to be a major problem.

Professional taxonomists
Professional taxonomists as discussed here are people who have a significant part of their work describing species or carrying out other taxonomic research. The number of such professionals in the U.S. or globally is unknown. There is general agreement that the number of taxonomists and taxonomic jobs is decreasing (Mikkelsen and Cracraft 2001; Agnarsson and Kuntner 2007; Chitwood et al. 2008; Drew 2011; Hauser 2011; Wild 2013; Foottitt and Adler 2017; Wilson 2017). There is an acknowledged shortage of suitable staff in some areas such as field pathology (Miller et al. 2009; Stack 2010), and Federal staff in a number of agencies interviewed in preparing this paper reported a lack of taxonomists available for some groups such as grasshoppers and mites. Retired staff are often relied upon; the National Museum of Natural History (NMNH) Entomology Staff directory lists more emeritus personnel, associates and collaborators than employed researchers, emeritus personnel alone being half as many as currently employed researchers. In the 1970s the SEL had 29 scientists, while it is now 15; SEL does not accept non-urgent identification requests for some taxa (although sends some non-urgent enquiries to external collaborators when staff are unavailable) (G. Miller *pers com.*; USDA - ARS 2016).

In addition to personnel loss, the strong but unofficial peer to peer networking is now breaking down as people retire or leave the field (S. Miller *pers com.*).

Existence of expertise does not guarantee EDRR capacity. A taxonomist in post may not be free to carry out identifications (Lyal and Weitzman 2004; Wild 2013). Taxonomists' activities are determined by their institutional and funders' priorities. Experts may also need time to develop their expertise, prepare identification tools, and revise the taxonomy of problematic groups. That such research is important is exemplified by the story of the Rasberry crazy ant in Houston, where different opinions and a very difficult taxonomic problem delayed effective management and permitted spread of the species (Gotzek et al. 2012; Wang et al. 2016). Consequently, merely evaluating the number of taxonomists in post gives little information on relevant capacity for EDRR. The declining number of taxonomists inevitably has a negative impact on identification capacity, and any solution must involve both increasing taxonomist numbers and their availability for effective EDRR.

Mapping invasive species risk profiles against identification capacity will inevitably reveal gaps both currently and as the potential invasive species pool changes (e.g. SEL does not cover some insect groups such as grasshoppers except when urgent [USDA - ARS 2016]).

No nation has sufficient taxonomic expertise to support identifications of all of their biota (SCBD 2007). Effective coverage of global biodiversity is even more challenging, and expertise is widely dispersed globally (Smith et al. 2008). The nature of invasive species means that relevant taxonomic expertise may lie in their countries of origin outside the U.S., and information may have to be sought from these specialists; international networks and contacts are required (Stack and Fletcher 2007, Stack 2009). This can pose problems that need resolution: locating experts; response time; management of experts; ability of a federal agency to issue a contract to pay for identifications; and impediments in sending specimens between countries from Access and Benefit-Sharing (ABS) regulations.

Identification of some groups relies particularly on one life stage, and absence of this limits or prolongs identification, especially if there are no taxon experts available (Hauser et al. 2009; Hauser 2011). Thus, although many insects can be identified only from adults, approximately half of submissions to SEL are immature. Specific identification tools may address this (e.g. on intercepted Lepidopteran larvae [Gilligan and Passoa 2014; LeVeen 2014]).

Expertise – aspects hindering rapid identification	Actions to increase rapidity
Expertise for authoritative identifications unavailable	All bodies employing taxonomists should: Increase support for systematics and taxonomy, both for native and especially invasive species. Develop identification expertise in life stages of organisms where no identification tools exist. Federal agencies should: Plan for necessary taxonomic expertise to be available within an EDRR structure. Develop efficient means to make use of taxonomists outside the U.S. where expertise is lacking. A model might include Australian Biological Resources Study (ABRS)'s grant program supporting projects facilitating areas that will boost Australia's taxonomic capacity. consider co-funding expert positions.
Professional identifiers unavailable	Federal agencies should: Recruit additional inspectors at PoE. Develop expertise to support identifications at regional level. Develop training programs for personnel at field and laboratory level, covering identification of known and potential invasive species, particularly understanding of techniques, resources, and tools. Build training programs into management systems to ensure that skills are regularly refreshed. Government should: Ensure funding to federal agencies to contract identification support, including use of eDNA.
Identifications slow	Federal agencies and the EDRRMC should develop incentives such as grants to develop identification tools, revise high-priority problematic taxa, and support taxonomic databases. Laboratories to train and recruit technicians to improve speed with which samples are processed and analysed.

Table 3. Expertise: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

Professional identifiers

Perhaps most identifications are undertaken by non-taxonomists employed to identify invasive species, particularly in quadrants A and C in Fig. 1. Key examples are PoE interception staff and employees of agencies supporting other pathway inspections. These government personnel can be regarded as professional identifiers. Most CBPAS hold a bachelor's or higher degree, and have taken a 12-week training course from USDA including pest and disease identification and quarantine regulations, supported by port-specific post academy training. There are ca. 2,400 CBPAS at PoE (Lapitan, 2016; Harringer 2016), staffing approximately half of the 329 PoE. CPB has reported a shortage of such experts in key high volume PoE, but CBP's Agriculture Program and Trade Liaison (APTL) has developed a dynamic "Agriculture Resource Allocation Model" to address staffing needs based on quantifiable volume and pest risk (Atsedu, *pers com.*; NISC Secretariat 2016a).

Other Federal agencies also have identification skills amongst their staff, although they too report lack of taxonomic expertise at site and regional levels.

Citizen scientists and affinity groups

Engagement of amateur communities can be more cost effective than researchers and produce more rapid identifications in cases of easily identified invaders (Goldstein et al. 2014; Lodge et al. 2016). Citizen science is perhaps most required in quadrants B and D of Fig. 1. Some citizen science groups are very local in their activities, benefitting from familiarity with local fauna and flora and sensitivity to unfamiliar species.

Groups might be encouraged to develop citizen science skills and engage in invasive species monitoring, even if they would not self-identify as being first responders. For example, existing interest in conservation photography among nature photographers (NANPA 2017) could be harnessed to submit high-quality images with GPS data to appropriate systems. The UK Riverfly Partnership (Riverfly Partnership undated) comprises conservationists, entomologists, scientists, water course managers, and relevant authorities, working together on aims centred around conservation; in the U.S. streamkeepers and others already monitor for invasive species (Johnson 2014), and a wider partnership could be developed with citizen scientists.

Citizen Science – Aspects Hindering Rapid Identification	Actions to Increase Rapidity
Too few citizen scientists engaged	1. All agencies and the EDRRCM: a. Increase understanding that the role of citizen science in management of invasive species is integral to future success, including to aquatic systems (USFWS 2015). b. Enhance citizen science programmes, including: i. public awareness activities; ii. outreach to selected groups; iii. recruitment program;
Identifications not of appropriate quality	1. EDRRCM, working with Federal agencies: a. Develop and implement identification protocols. b. Develop and implement training systems, including on the use of identification tools and the capacity to provide suitable information to the appropriate authorities who can take action c. Develop and implement appropriate management techniques for citizen science reports, including data quality.

Table 4. Citizen science: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

Citizen scientists may not be able to provide information with as consistent a level of reliability as specialists (Newman et al. 2010; Lewandowski and Specht 2015); accuracy may decrease with rarer encounters (Swanson et al. 2016). Reliability is improved with appropriate training (Newman et al. 2010; Gardiner et al. 2012; Freitag et al. 2016) and observation and analysis protocols (Tweddle et al. 2012). Most if not all states have Master Gardener and Master Naturalist programs, and Collaborative and Enhanced First Detector Training programs exist at state or network level, e.g. by NPDN (NPDN undated) and Bugwood (Hummel et al. 2012). These programs increase understanding of relevant agency responsibilities, including the appropriate IPC to bring specimens before specialists (Stubbs et al. 2017).

Collections

Biological collections are a key tool to support rapid identification of invasive species and provide information on distribution, origin and biology etc. (Simpson 2004; Suarez and Tsutsui 2004; Smith et al. 2008; IWGSC 2009; Gotzek et al. 2012; Lavoie 2013); they also provide material to develop molecular tools (Hubert et al. 2008; Galan et al. 2012). To meet these needs relevant collections need to hold examples of both native and non-native species to enable comparison, and specimen identifications need to be correct; this cannot be assumed (Goodwin et al. 2015; Jacobs et al. 2017; Sikes et al. 2017).

Observations, molecular tools and DNA sequences should be vouchered by physical specimens in collections (Ratnasingham and Hebert 2007; Packer et al. 2018). For example, the NMNH collections at the SI are the official repository for vouchering arthropods collected with Federal funding. Culture collections have a less clear model. USDA maintains several culture collections, including ARS (USDA - ARS 2017), and Ft. Dietrich for invasive species. The American Type Culture Collection (ATCC 2017) charges for deposit and retrieval, and consequently some researchers send strains overseas (McClusky *pers com*). Despite initiatives such as the US Network of Culture Collections (McCluskey et al. 2017) there is poor U.S. infrastructure for microbial collections, with problematic funding support (Smith 2017).

The last detailed survey of U.S. systematic collections was 1988, with publications on insects (Miller 1991) and fish (Poss and Collette 1995); Hafner et al. (1997) produced a review of mammal collections. Gropp and Mares (2009) predicted funding issues in the NSCA 2008 survey of North American (federal and non-federal) collections. While most federal collections are growing there have been problems with declining numbers of trained staff and funding resources (IWGSC 2009). Information on U.S. Federal Scientific Collections is available on-line (USFSC 2017) including a keyword search on "invasive".

Non-federal collection-holders include private bodies and non-governmental bodies such as universities. Unlike federal collections, for which proper care is required by Public Law 111-358 section 104, there is no guaranteed sustainability. For example the University of Louisiana at Monroe recently disposed of its collection of ca. 6 million fish and half a million native plants. As with federal collections, declining staff numbers are an issue (Kemp, 2015).

Laboratories

Federal, public, and private laboratories provide diagnostics and identifications of whole organisms, micro-organisms, or fragments (Trebitz et al. 2017). Some are operated by collection-holding institutions, others by federal agencies (e.g. USDA's CPHST Beltsville laboratory). Both animal and plant diseases are served by networks of laboratories (NPDN 2017; USDA - APHIS 2017b; https://www.nahln.org/), and networks with wider collaborative potential such as FICMNEW. Both California and Florida have large State Department of Agriculture laboratories that identify agricultural organisms, while some other states maintain smaller laboratories. No information is available to assess whether the capacity of the extant laboratories is sufficient for an EDRR program, although NPDN and NAHLN operate in a competitive funding environment, and the use of private facilities suggests insufficient federal capacity.

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Collections and Laboratories – Aspects Hindering Rapid Identification	Actions to Increase Rapidity
Collections at risk of loss, or inaccessibility through lack of staff	Agencies with scientific collections should ensure support for long-term sustainability of collections for invasive species activities (Miller 1991; Pape 2001; ESA 2016).
Specimens for comparison unavailable	Collection-holders should ensure they have holdings of relevant native and possible invasive species.
Specimens for comparison incorrectly identified	Collection-holders should take steps to confirm the identity of invasive species in their collections.
Diagnostic laboratory capacity insufficient	Relevant stakeholders should ensure sustainable funding for federal and other public laboratories to provide identification and diagnostics. Funding as research bodies rather than identification services will attract desirable levels of expertise.

Table 5. Collections and Laboratories: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

Identification Tools

Identification rapidity can be increased by providing identification tools, particularly at or near interception points (all quadrants in Fig. 1). Martinez et al. (2018) discuss such tools, but there are also capacity issues, since taxonomic expertise is required to create the tools and update them to reflect changes in taxonomy or novel invasives.

Molecular Tools

Molecular tools permit rapid non-specialist identification (Hubert and Hanner 2015). Use of DNA barcodes (Rugman-Jones et al. 2013), or eDNA (Wilcox et al. 2015) makes it possible to detect and identify invasive species effectively and to a rigorous standard (Frewin et al. 2013), and eDNA allows detection even when only few specimens are present.

Increasing use of barcodes may reveal unnamed cryptic species, referred to by the Barcode Index Number (BIN) system (Miller 2015). However, names will be required to relate these to extant information, requiring expertise from a taxonomist of the group (Sheffield et al. 2017).

Use of molecular data relies on a library of DNA sequences (DNA barcodes, other selected genes, or genomes) to identify sequences from unknown organisms. Although large, these libraries are incomplete (Adamowicz et al. 2017); Wilkinson et al. (2017) estimate that Barcode of Life Data System (BOLD) holds core DNA barcodes for only 15% of land plant species, and intraspecific coverage is even less complete. Some groups have more than 90% coverage for an intensively-sampled area (Zahiri et al. 2017), but may omit non-native species (Hauser 2011). Many correspondents expressed the importance of a global barcode library (S. Miller, Lodge and Pecor *pers comm*), with a priority given to pest species, particularly those with a high likelihood of invasion (S. Miller *pers com*); the Walter Reed Biosystematics Unit (WBRU) is building a BOLD database of mosquitoes and other disease hosts. Expanding coverage and improving quality may require development of new tools (Wilkinson et al. 2017).

Genetic markers for eDNA also need developing, especially for novel invasives, although those already developed may not be widely known. Obtaining samples of target species from outside the USA can be difficult and leads to prioritisation of easily-obtained species (Great Lakes

USFWS team, *pers com*). Increasing sensitivities in many countries around ABS (SCBD 2017) and the use of digital sequence information will need to be managed effectively to facilitate this.

DNA methodologies have limitations. Different genes, even 'DNA barcodes', perform at different accuracies (Braukmann et al. 2017; Wilkinson et al. 2017). Assays differ in resolution (Amberg et al. 2015), and next-generation may provide a higher resolution than Sanger sequencing (Batovska et al. 2017). While many studies report over 95% accuracy, claims of 100% accuracy have not been seen. Some taxa have not proven amenable to determination using barcodes (Piredda et al. 2010; Pyšek et al. 2013).

DNA use is evolving rapidly (e.g. Ardura et al. 2017; Wilkinson et al. 2017). However, more papers test new methodologies for potential value in invasive species detection than report their adoption as embedded systems. While accuracy and rapidity in detection is improving, this does not automatically lead to field use. Variation in results obtained using different methodologies and continual methodological changes might limit acceptance (Lodge, *pers com*; Great Lakes USFWS team, *pers com*); federal agencies with diagnostic standards may require careful evaluation and official approval of methodologies (e.g. USFDA 2017a). Despite this, many federal agencies are using DNA-based techniques and even extending them, as are USGS with eDNA detection kits for Asian Carp (NISC Secretariat 2016b; Great Lakes USFWS team *pers com*); eDNA tools for sea lamprey in the Great Lakes are under development (Gingera et al. 2016). Correspondents stressed that much of the eDNA work was scalable, but would take additional funds to roll out further.

An issue with expanding sequencing work is the volume of assays possible. USGS has 3 sequencers with capacity to produce more than 800,000,000 reads in less than 48 hours; due to the large volume of data generated they have had to invest in infrastructure to store and process them. Increasing use of sequence data will inevitably cause such costs to rise.

Open Tools for General Use

There are many identification tools including literature (field guides, dichotomous keys, identification cards, etc.), web sites, and phone apps (Martinez et al. 2018). While the number of apps is increasing they are insufficient to address all species that might be prioritised. State-level coverage varies, but because of differing biota it is problematic to use an app developed for one state in another. There is no overall plan to ensure all priority invasive species are covered at the appropriate geographical level, nor is there a means of quality assessment.

Identification tools may be tailored to pathway or targeted inspections (Fig. 1 quadrant C) or general use (Fig. 1 quadrant B), priorities for the former may be easier to set than for the latter.

The many web-based resources vary considerably in quality, can be difficult to locate, and may not include all species that might be intercepted (Stack et al. 2006); user assumptions that everything is included may lead to false positives.

Although images do not ensure accurate identifications (Austen et al. 2016) their use can be vital. Accuracy requires good images, clearly marked diagnostic features and comparison with similar native species (e.g. Tsiamis et al. 2017). Comparing images of different species facilitates identification, but some systems do not allow this (e.g. Invasive.org undated; iNaturalist 2017). Images not indicating diagnostic features between similar species may lead to errors (Vantieghem et al. 2017). Tools focusing on relatively easy-to-identify groups such as bumblebees, ladybirds etc. may function well, but visual-based tools are inappropriate for more cryptic, less well-marked or smaller species.

USDA and other federal agencies might not accept tools such as iNaturalist because there is no quality assessment (S. Miller, *pers com*), although NPS uses it and the USGS BISON uses iNaturalist images (USGS 2017). There is no U.S. equivalent to the Australian PaDIL (http://www.padil.gov.au/) which provides images and characters for a wide range of exotic organisms in its "Plant Biosecurity Toolbox."

Identification Tools – Aspects Hindering Rapid Identification	**Actions to Increase Rapidity**
Insufficient non-molecular tools for widespread use	1. Federal agencies, universities and research bodies should: a. Develop tools for professional and citizen science use, including apps to cover all priority invasive species that can be identified using these methods, making them site-appropriate where needed. b. Prioritise development of non-molecular or molecular tools to support identification of regularly intercepted problematic life stages.
Tools may not be of appropriate quality to produce accurate identifications	1. EDRRCM should: a. Encourage development of and promote standards for tools such as apps b. Develop resource list of tools meeting standards to increase availability, with reviews of their suitability for different taxa and geographical regions 2. Stakeholders producing apps and other tools should adopt standards proposed by EDRRCM
Sequence libraries incomplete	1. Federal agencies, universities, research bodies, relevant database owners and collection-holders should: a. Expand authoritative vouchered genetic sequence libraries: i. Complete a global DNA barcode library. ii. Develop eDNA markers for high priority species iii. Ensure availability of tissue samples from reliably identified and uncontaminated voucher specimens. Facilitate sourcing specimens from outside the U.S., including managing ABS regulation requirements. iv. Prioritise pest species for future DNA library entry and data quality re-evaluation, particularly those with a high likelihood of invasion.
Sequencing facilities and expertise insufficient or unavailable	1. Federal agencies should: a. Foster collaborations and partnerships between each other and internally to increase access to sequencing and bioinformatics capabilities b. Increase access to bioinformaticians, bioinformatics analysis programs and database development by their staff. c. Invest in hardware to expand sequencing efforts.

Table 6. Identification tools: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

Reliability Measures

Responses to reported invasive species are potentially costly and likely to be triggered only when sufficient evidence is available from a risk assessment, including identification reliability. This can be assessed by (i) reliability (authority) of the identifier; (ii) reliability of the diagnostic laboratory; and (iii) identification methodology.

Although standards provide a measure of assurance, every system carries a risk of false positives or false negatives. An EDRR system needs a means of assessing identification reliability to determine response, balancing the risk of taking action without sufficient authority against risks attendant on increasing time through seeking maximum authority. Setting identification standards will assist this judgement.

Identifier Authority and Accuracy

There is little clarity on requirements for recognised identifier expertise, and criteria will differ along the IPC. CBPAS must have their identifications checked by a relevant authority. Since PoE interceptions may have legal consequences, identifiers might have expert witness status (although court appearances are rare for ARS taxonomists [G. Miller *pers com*]). Taxonomists do not have a certification system; instead they are judged on qualifications, publications and experience. Overall there are to be limited options to standardise identifier authority other than training and workplace monitoring if employed in this capacity. For citizen scientists there are courses available in invasive species identification, and the more tailored they are to sites or species the better the personnel will be equipped and the more accurate identifications are likely to be. However, since often citizen scientists will be operating in quadrant B of Fig. 1 where the potential for error is highest, protocols to manage identification submissions should be used (Chandler et al. 2017; MacKenzie et al. 2017).

Laboratory Standardisation and Quality Assessment

Some federal agencies apply laboratory standards (USDA – FSIS undated; FBI DNA Advisory Board 2010; USDA - APHIS 2013). A relevant International Organization for Standardization (ISO) standard is adopted by USDA CPHST Beltsville Laboratory (ISO 2017), which is a key component of the Plant Protection & Quarantine (PPQ) National Plant Pathogen Laboratory Accreditation Program (NPPLAP) (USDA – APHIS undated a). ISO is developing a biobanking standard which will be modified for various collection types (ISO undated). Private contractors may have industry standards and accreditations.

Standardisation of Identification Methodologies

In developing EDRR protocols the identification methodology should be specified (e.g. FICMNEW 2003; Rabaglia et al. 2008; Trebitz et al. 2017).

There is no standard definition of a species, either federally or between taxonomists, and agencies apply different standards to identifications depending on their governing laws and policies. This may limit agencies' ability to make use of identifications from others. The U.S Federal Bureau of Investigation (FBI) uses the best available published science, but other agencies rely on their own internal laboratories and procedures. U.S. federal law makes use of the Daubert Standard to assess the validity of expert evidence (Berger 2011); some principles may be transferable.

There are some standards for individual species identifications. Some U.S. agencies use International Plant Protection Convention (IPPC) standards (FAO - IPPC 2017) (Bostock et al. 2014; USDA - APHIS 2017d), but most species are not covered by these. USGS and USFWS laboratories have established sampling methodology and laboratory proficiency standards for molecular detection of *Batrachochytrium salamandrivorans* (NISC Secretariat 2016c). The Food and Drug Administration (USFDA) uses the "Regulatory Fish Encyclopedia" (USFDA 2017b), including DNA barcodes and electrophoretic methods, and maintains a Reference Standard Sequence Library for Seafood Identification (RSSL) (USFDA 2017a). Mickevich (1999) sets out some criteria for identification and quality of names included in databases.

The USDA Food Safety and Inspection Service (FSIS) makes available an unendorsed list of test kits that have been validated for detection of pathogens (USDA - FSIS 2017), and guidance to evaluate the performance of pathogen test kits (USDA - FSIS 2010).

There are formal guidelines for DNA Barcode inclusion in BOLD, which include vouchering a specimen (Ratnasingham and Hebert 2007; Hanner 2009).

Standards – Aspects Hindering Rapid Identification and Response	Actions to Increase Rapidity
Uncertainty on correctness of identification;	1. EDRRCM should: a. Commission standard identification requirements for high-risk species for adoption by agencies; b. Review identifier accreditation options and propose standards; c. Consider setting and adopting requirements for laboratory accreditation, including required expertise and tools.
Challenges in working across agencies	1. EDDRRCM in partnership with federal agencies should develop identification protocols at national or regional levels, to promote standardisation and regulatory acceptance across agencies.

Table 7. Standards: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

Taxonomic Name Management

Taxonomic names change as a result of scientific study (Vecchione 2000) at perhaps 1% per year (Smith et al. 2008). A standard list of names is important for information exchange and assessing and managing possible invasives (Smith et al. 2008; Pyšek et al. 2013; Deriu et al. 2017; Groom et al. 2017), allowing stakeholders to have a single point of reference and remove ambiguity. Data management issues around name providers are addressed by Wallace et al. (this volume), but there are capacity issues in compiling and maintaining the databases and interpreting and using the contents.

Names Used

Rapidity of identification needs to be matched by all stakeholders using the same name and species concepts; otherwise there are risks of miscommunication and using incorrect names. There is no single global source of all scientific names, nor complete list of U.S. native or invasive species. Without such a list even at state level, an agency cannot always tell what species are non-native (Great Lakes USFWS team, *pers. com.*).

An authoritative source (name-server) for the currently used names for U.S. federal agencies, the Integrated Taxonomic Information System (ITIS) (Guala 2016) is used by EPA (USEPA 2000) and USGS, and is recommended to its agencies by the Department of the Interior (DOI) (and used by the European Invasives Species database EASIN [Deriu et al. 2017]). However, gaps in coverage, including of agriculturally important insects, currently preclude its use by USDA.

There are many catalogues and name-serving databases, differing according to the resources used in compilation, the taxonomists producing them, update frequency and coverage. They may give different names for the same organism, or omit species. Expert taxonomists may not refer to databases, but use the most recent scientific literature, often not captured by name-servers. Names supplied by experts may therefore not be relatable to names being used by other stakeholders. Different identification tools may also use different names for the same species.

There are hidden risks associated with *species concepts*. Different names applied over time may not be simply and unequivocally linkable to biological entities. If a species is moved between two genera (e.g. the crazy ant *Paratrechina fulva* Mayr is re-named *Nylanderia fulva* Mayr) the two names refer to the same *species concept* with the same biological properties. When two species are discovered to be the same they are subsequently known by the older name, and again share the same species concept. In both these examples users need to locate information published under both names, so databases should have both (ITIS undated; Guala 2016). However, sometimes what was thought to be a single species is discovered to comprise different entities, e.g. the red palm weevil comprising two species: *Rhynchophorus ferrugineus* (Olivier) and *R. vulneratus* (Panzer) (Rugman-Jones et al. 2013), and biological and other observations recorded under the original name cannot with confidence be applied to one or other of the new concepts. Barcode "provisional nomenclature" to enable reference to informal concepts may assist (Schindel and Miller 2009). The issue compounds the problems of unconnected databases. Although there are attempts to manage concepts in databases (e.g. Franz and Peet 2009) no solutions are accepted widely. Notably, most databases lack a mechanism for alerting users of changes in names or concepts.

Federal agencies use a variety of name providers, some referring to different providers in different documents. There may be static lists either included in the document e.g. USDA (2012b) or online e.g. USDA – APHIS (undated b), or online databases e.g. ITIS (undated).

Some USDA preclearance manuals include lists of plant names that shippers should use, including: manual-specific list derived from the literature or unstated sources, Parasitic Plants Database, CITES Species Database, Federal Noxious Weed List, Endangered Species Act (ESA) Listed Plants, and U.S. National Plant Germplasm System (GRIN). In some manuals differences between sources are mentioned. PoE inspectors are consequently aware of what is stated as in a consignment but, because there is no standard source of names for the shipper (or quarantine staff) to use, some of the identities may be questionable.

Some name-serving databases are context-specific, although this can be confusing. The Federal Noxious Weed List (USDA - APHIS PPQ 2010) is a PDF listing 108 species reached from a website "Federal Noxious Weeds" (USDA - NRCS 2017) listing 112 species which is derived dynamically from the PLANTS database (USDA - NRCS 2018). The USDA *Seeds Not for Planting Manual* (USDA 2014b) link named "Parasitic Plants Database" leads to an undated PDF list of genera with the latest supporting reference dated 2003 (USDA – APHIS undated b). The Bureau of Land Management has lists of weeds of concern that "comply with" the Federal Noxious Weed Lists, State Noxious Weeds Lists and county lists, compiled by a range of stakeholders (NISC Secretariat 2016d). The California Department of Food and Agriculture list of weeds (CDFA 2018b) differs from the USDA California list from the PLANTS database. Inevitably some names on these lists differ even though they refer to the same species. A brief inspection of the U.S. Regulated Plant Pest Table (USDA - APHIS 2017e) revealed a number of outdated names. Species listed present (e.g. state lists of invasive species) depend on identification accuracy. Erroneous identifications and unreliable documentation in area lists can lead to large errors (Vecchione 2000).

A global database tailored for Invasive Species, the Global Invasive Species Database (ISSG), is not referred to in any documents seen, even though an early version of this identified nearly 200 species from a list of imports into the U.S. between 2000-2004 that might pose a risk to the U.S. (Browne et al. 2007). BISON (USGS, 2017), a web-based federal mapping resource for species occurrence data in the U.S. and its territories (Guala 2017) will tag records as invasive where possible (although this will not indicate invasive status between states in the lower 48). BISON draws on ITIS names plus resources including iNaturalist and collection records.

The resources used across federal bodies to provide scientific names do not all exchange information, and are not equally complete or up-to-date, some delivering outdated names or concepts. Some online PDFs are undated, and resources may not be removed from the internet when superseded. ITIS and the PLANTS databases have recently agreed to share resources and

Standards – aspects hindering rapid identification and response	**Actions**
Miscommunication through using different names	1. EDRRCM and name-servers should raise awareness among stakeholders of potential disparities between databases 2. Federal agencies should: a. Take steps to harmonise resources used for names. b. Support major publicly-funded databases, and facilitate closer collaboration between them.
Duplication and errors arising from use of different databases	1. Name-servers (databases) should work together to develop a single portal to names of all organisms, building on existing investments (e.g. ITIS, PLANTS). a. Duplication of effort should be avoided. b. Names should be as up to date and stable as possible. c. Names should include all U.S. native taxa. d. Names should include non-native species known to have entered the U.S. and species at risk of entering the U.S. e. Synonyms should be included. f. Unique identifiers for names should be used (e.g. ITIS Taxonomic Serial Number [TSN]).
Errors through incomplete or outdated databases	1. Federal agencies and funders should support taxonomists and name-servers to complete and maintain an authoritative database / federated database of names of native and invasive species. 2. Federal agencies should make use of global databases of invasive species. 3. Name-servers should: a. Agree and implement a universal indication of record quality. b. Develop systems to alert stakeholders when a name is changed or new invasive species is detected in the U.S. (building on the USGS Nonindigenous Aquatic Species database national alert system).
Concept changes not understood	1. Name-servers should develop means of showing concept changes.

Table 8. Taxonomic names: Recommendations. See Table 1 for relevance to a sustainable taxonomic resource for EDRR.

bring their taxonomies into alignment. PLANTS is linked to GRIN (USDA - ARS 2015). This process needs support, as does continued population of the databases with appropriate quality control. ITIS stipulates high record quality and provides compilation date, but more extensive criteria to show scrutiny level and verified accuracy were proposed by Mickevich (1999) and Mickevich and Collette (2000) for the NOAA / NMFS marine database.
Watch lists are developed by federal and state bodies, including by the NPS Service Exotic Plant Management Teams (EPMT) for National Parks; the Heartland EPMT methodology was by using consensus in the summarized findings of other lists (NISC Secretariat 2016d). However, harmonised lists cannot be produced simplistically (Pyšek et al. 2013; Murray et al. 2017).

Names Recognised in Legislation

Names used in legislation or management protocols may not track changes in scientific nomenclature and may refer to outdated concepts, thus not relating to currently recognised problem species. There are procedures for adding names to the Lacey Act list and some of its listed names include alternative scientific names. Some names are listed in legislation at the genus or higher taxonomic level. Thus, when an unexpected diversity was discovered in the snakehead (Conte-Grand et al. 2017) this had no regulatory impact because the family is listed in the Lacey Act (USGS 2004).

CONCLUDING NOTE: THE TAXONOMIC IMPERATIVE

The provision of taxonomic support in the U.S. is under threat. Taxonomists are retiring and leaving the profession, and positions are not being replaced (Stack et al. 2006). Plant diagnostic laboratories are being impacted by decreasing state support, and dependence on fees reduces submission of samples (Stack et al. 2006). State universities are disposing of collections and staff, and losing the capacity to manage the collections they hold. Fragmentation and isolation of resources and duplication of databases make expertise and information difficult to locate and use with confidence. Action at a local level may be insufficient when the required information or expertise is only available when seeking at a global scale.

Underlying almost every area is a need to improve collaboration between federal and state agencies, and development of coherent taxonomic support with sufficient expertise rapidly and easily available. If federal and state agencies continue to operate in the current fragmented and sometimes ad hoc manner an efficient and effective EDRR is unlikely, posing a serious risk of invasive species going unmanaged.

The U.S. does not have a strategy to address the need for rapid identification under EDRR. Such a strategy is needed urgently. Because the U.S. cannot provide all of the expertise and resources it needs to manage identification of intercepts from other countries, it must have an interest in global capacity. International networks of taxonomists have been set up, the most extensive being BIONet-International (Jones 1995), although this has been inactive for the past five years. Such networks could be revived to support the U.S. and other countries in identification of invasive species. Networks across the world and within the U.S. need to be resourced to be sustainable and provide the input required for EDRR. With a critical approach to EDRR and investment in taxonomic capacity the current risks to effective management will be addressed sustainably.

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