

## Viewpoint

## INVASIVESNET towards an International Association for Open Knowledge on Invasive Alien Species

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### Abstract

In a world where invasive alien species (IAS) are recognised as one of the major threats to biodiversity, leading scientists from five continents have come together to propose the concept of developing an international association for open knowledge and open data on IAS—termed “INVASIVESNET”. This new association will facilitate greater understanding and improved management of invasive alien species (IAS) and biological invasions globally, by developing a sustainable network of networks for effective knowledge exchange. In addition to their inclusion in the CBD Strategic Plan for Biodiversity, the increasing ecological, social, cultural and economic impacts associated with IAS have driven the development of multiple legal instruments and policies. This increases the need for greater co-ordination, co-operation, and information exchange among scientists, management, the community of practice and the public.

INVASIVESNET will be formed by linking new and existing networks of interested stakeholders including international and national expert working groups and initiatives, individual scientists, database managers, thematic open access journals, environmental agencies, practitioners, managers, industry, non-government organisations, citizens and educational bodies. The association will develop technical tools and cyberinfrastructure for the collection, management and dissemination of data and information on IAS; create an effective communication platform for global stakeholders; and promote coordination and collaboration through international meetings, workshops, education, training and outreach.

To date, the sustainability of many strategic national and international initiatives on IAS have unfortunately been hampered by time-limited grants or funding cycles. Recognising that IAS initiatives need to be globally coordinated and on-going, we aim to develop a sustainable knowledge sharing association to connect the outputs of IAS research and to inform the consequential management and societal challenges arising from IAS introductions. INVASIVESNET will provide a dynamic and enduring network of networks to ensure the continuity of connections among the IAS community of practice, science and management.

**Key words:** knowledge flows, network of networks, sustainable, IAS management, communication platform

## Background

Increasing travel, trade, agriculture, tourism, as well as globalization and/or human expansion have continued to facilitate intentional and unintentional movement of species beyond their natural borders (Lenda et al. 2014; van Kleunen et al. 2015; Essl et al. 2015; Canning-Clode 2016). A great many of these alien species have become invasive and had extraordinary environmental, ecological, economic, societal, and cultural impacts in recipient communities. For example, invasive alien species (IAS, for definitions in this paper see Box 1) are considered one of the main drivers of global biodiversity loss [CBD 2016; Millennium Ecosystem Assessment 2005 (<http://www.millenniumassessment.org>)]. They can also cause severe economic losses, risks to animal, plant and human health and create societal and cultural impacts (Vilà et al. 2010; Cliff and Campbell 2012; Conn 2014; Mazza et al. 2014; Katsanevakis et al. 2014; Ojaveer et al 2015; Bellard et al. 2016; Pergl et al. 2016). Furthermore, these effects are expected to accelerate as more species spread beyond their historic borders due to (1) further globalization; (2) land-use and sea-use change; (3) climate change (Bellard et al. 2013; Seebens et al. 2015); (4) spatiotemporal changes in IAS vectors and pathways, and (5) the effects of complex interactions between all these factors (Walther et al. 2009; Essl et al. 2015; Galil et al. 2014a, b; Galil et al. 2016).

Global policy and decision makers have responded to the growing challenges posed by IAS with the development of legal instruments, such as the EU Regulation on Invasive Alien Species (EU 2014; Genovesi et al. 2015; Tollington et al. 2015). There are also voluntary codes of conduct, such as “A code of conduct on invasive alien species for Europe's botanic gardens” (Heywood and Sharrock 2013). Multilateral Environment Agreements (MEAs), such as the Convention on Biological Diversity (CBD), Ramsar Convention on Wetlands, Convention on the Conservation of Migratory Species of Wild Animals (CMS), Sanitary and Phytosanitary measures of the International Plant Protection Convention (IPPC), and World Organisation of Animal Health (OIE), all address aspects pertaining to invasive alien species, variously encouraging member States to prevent the introduction of alien and invasive species and to manage established populations. In particular, Target 9 of the Aichi Biodiversity Targets in the CBD Strategic Plan for Biodiversity 2011–2020 is focused on invasive alien species (CBD 2010). In similar fashion, the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) has identified the need for a thematic global

assessment on invasive alien species and their control (Deliverable 3(b)(ii)) (IPBES 2016).

Additionally, in the arenas of global human health and international pandemic preparedness, there are concerns with international dissemination of disease vectors and reservoirs, many of which are proven or potentially IAS. These are addressed in numerous articles of the International Health Regulations (IHR 2005), administered by the United Nations (UN) and coordinated through the World Health Organization (WHO).

Environmental management should be evidence-based (Sutherland et al. 2004). Having access to sufficient accurate information on invasive alien species with regard to their pathways of introduction, life history, evolution, distribution, abundance, impacts, and effective control and containment strategies will improve the effectiveness of IAS regulations, risk analysis and management. Risk assessments for new IAS species conducted in one location are inherently dependent on high-quality data (e.g., environmental variables describing suitable habitats) from all donor regions. As researchers around the world are working to assess the same pathways, vectors and species (Essl et al. 2015), using similar tools for management, there is a clear need for global coordination of data and lessons learned to avoid redundancies, increase consistency, and to advance research efficiency. The knowledge base in invasion science needs to be more comprehensive for IAS management, including information on ecological, cultural, social and economic challenges (Esler et al. 2010; Ojaveer et al. 2015).

The scientific community plays a critical role in generating informed, reliable, high quality, and evidence-based IAS-related information. Targeted efforts are needed for transferring this knowledge in efficient ways to decision makers, environmental managers and the general public. Concurrently, IAS researchers should work with stakeholders, in particular, managers and practitioners who experience day-to-day problems caused by IAS. As such, developing efficient evidence-based IAS information not only requires increasing the amount of information produced by the scientific community, but doing so in a way that reshapes how knowledge is exchanged and used in practice (Young et al. 2014). In addition, information from communities of practice (Wenger et al. 2002) can provide guidance for managers in the science-management knowledge interface (Roux et al. 2006), and this gives a dual flow to the knowledge base (Figure 1).

Since the mid-1900s civic awareness of invasive species issues has greatly increased (Lowry et al. 2013), with a consequent need to prioritize the development and adoption of innovative and effective communication tools and methods for use by IAS

**Box 1. Definitions.**

For the present paper, we use definitions adopted by Decision VI/23 of the Conference of the Parties to the Convention on Biological Diversity at its sixth meeting, The Hague, 7–19 April 2002 (CBD 2002). Specifically,

“alien species” refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce;

“invasive alien species” means an alien species whose introduction and/or spread threaten biological diversity (For the purposes of the present guiding principles, the term "invasive alien species" shall be deemed the same as "alien invasive species" in decision V/8 of the Conference of the Parties to the Convention on Biological Diversity);

“introduction” refers to the movement by human agency, indirect or direct, of an alien species outside of its natural range (past or present). This movement can be either within a country or between countries or areas beyond national jurisdiction;

“establishment” refers to the process of an alien species in a new habitat successfully producing viable offspring with the likelihood of continued survival;

“risk analysis” refers to: (1) the assessment of the consequences of the introduction and of the likelihood of establishment of an alien species using science-based information (i.e., risk assessment), and (2) the identification of measures that can be implemented to reduce or manage these risks (i.e., risk management), taking into account socio-economic and cultural considerations.



**Figure 1.** Knowledge flows among IAS Community of Practice, Science and Management.

stakeholders (Caffrey et al. 2014; Daume 2016; Adriaens et al. 2015). Following their development, these new technologies, such as downloadable software applications (“Apps”) often funded by projects, require an assessment and evaluation process to determine their long term efficacy. Recently, the implementation of new open data governmental policies and initiatives (e.g., US Exec. Order No. 13642 2013; Bouchout Declaration 2014; IPBES 2016) has resulted in strong encouragement for wide dissemination of reliable IAS-related information. In this regard, new IAS smart tools are an effective way to engage citizen science and to increase knowledge flows.

Citizen science can be a useful way to support research and monitoring for IAS by providing valuable information across spatial and temporal scales (providing that “citizen science” is accompanied by rigorous protocols of quality assurance and quality control). By mapping, integrating and coordinating reliable and verified IAS data sources, citizen science can capture information that otherwise would be unfeasible to document via professional surveys alone (Crall et al. 2010; Crall et al. 2015; Groom et al. 2015; Roy et al. 2015; Pocock et al. 2016). Not only does this contribution address data deficiencies, citizen science provides additional benefits to society,

including reduced cost and improved science and technology literacy among participants (Crall et al. 2015). Public engagement contributes to a better understanding of IAS across society and is crucial for tackling a global environmental issue like IAS.

The European Commission Open Access policy aims to optimise the impact of publicly-funded scientific research by placing high emphasis on open science for dissemination, deployment and transformation of research by digital tools, networks and media. It relies on the combined effects of technological development and cultural change towards collaboration and openness in research (<https://ec.europa.eu/digital-single-market/en/open-science>). At a recent EU Council meeting, member States agreed to common goals on open science and to pursue concerted actions together with the Commission and stakeholders at all levels in society. Delegations committed to open access to scientific publications as the option by default by 2020 and to the best possible re-use of research data as a way to accelerate the transition towards an open science system (Council of the EU, 9357/16, 9526/16).

Many projects and programmes have received funding to research and act as IAS information sources. However, problems with economic sustainability have already resulted in the closure or suspension of several global and regional initiatives on IAS, including the Global Invasive Species Programme (GISP 2010). Further development of many important information resources on IAS is also hampered by time-limited grants [e.g. AquaNIS 2015; DAISIE 2016; GISD 2016; GISIN 2016; NIMPIS 2009; NOBANIS 2016; WRIMS (Pagad et al. 2016)]. Sustainability is always a challenge and is exacerbated by economic downturns that often increase funding cuts and reduce the effectiveness of fund raising initiatives. Invasive species are long-term concerns and require long-term strategic funding and direction to weather the effects of short-term economic downturns and political attention and funding cycles (the issue-attention cycle *sensu* Downs 1972). Sustainability is also a concern for regional, national and local IAS activity, including national information systems, expert networks, and monitoring systems, many of which act as primary sources of information for global initiatives (Katsanevakis et al. 2013; Vanderhoeven et al. 2015). This problem is not unique to IAS, but to all data and information infrastructures (Costello et al. 2014), and this problem can be mitigated if the infrastructure is globally significant, comprehensive, high quality and with strong support from the scientific community (Costello et al. 2014).

Scientists and environmental managers recognize that the momentum created by many communication

initiatives needs to be maintained in the long term (Ricciardi et al. 2000; Simpson et al. 2006). Hence, there is an urgent need for a new global initiative to sustainably link existing expert networks and initiatives on IAS (for a list of current IAS-related networks and initiatives involving authors of this viewpoint paper, see Box 2) with an expanded spectrum of interested stakeholders. This would also support already existing and worthwhile initiatives, while enabling innovative communication methods and relevant services for all interested bodies, in particular the scientists and citizen scientists who both provide and use IAS-related data and other research outputs. In this regard, existing thematic open access journals (Kühn et al. 2011; Panov et al. 2011; Lucy and Panov 2012; Campbell 2013) may serve as a core element for such an initiative, with the ultimate aim of developing a widely sustainable **network of networks** on IAS.

## Concept

**The International Association for Open Knowledge on Invasive Species (INVASIVESNET)** is a new bottom-up initiative created by concerned scientists aimed at developing a sustainable global **network of networks** on IAS. The Association will be formed by linking interested stakeholders and their networks including scientists and citizens, international and national expert working groups and initiatives, database managers, editorial boards of thematic open access journals, interested environmental agencies, practitioners and managers, affected and responsible industries, non-governmental environment protection organizations and educational bodies. The association will work as a community of practice, allowing networking opportunities, knowledge sharing and learning for each participant. This will promote more coordinated and managed ways to co-operate and to openly communicate research results so that IAS management can be more efficiently transferred among all levels.

INVASIVESNET aims to produce high-quality communication, information, publication and education services (Figure 2). By recruiting all interested and committed stakeholders as members of INVASIVESNET and through collaborative activities, we will maximize the sustainability of this initiative, while also taking due consideration of all member interests. Consistent with the journal activities of many long-established scientific associations, the sustainability of this initiative will also be maintained via the incorporation of existing thematic open access journals as a core linking element of INVASIVESNET (Figure 2).

**Box 2. Thematic expert networks and other IAS-related initiatives served by authors.**

*IAS-related Networks*

Global Invasive Species Information Network (GISIN)	<a href="http://www.gisin.org">http://www.gisin.org</a>
Global Invasions Research Coordination Network (GIN)	<a href="http://invasionsrcn.si.edu">http://invasionsrcn.si.edu</a>
EU COST Action TD1209 Network (Alien Challenge)	<a href="http://www.brc.ac.uk/alien-challenge/">http://www.brc.ac.uk/alien-challenge/</a>
European Network on Invasive Alien Species (NOBANIS)	<a href="https://www.nobanis.org">https://www.nobanis.org</a>
European Research Network on Aquatic Invasive Species (ERNAIS)	<a href="http://www.reabic.net/ERNAIS.aspx">http://www.reabic.net/ERNAIS.aspx</a>
East and South European Network for Invasive Alien Species (ESENIAS)	<a href="http://www.esenias.org">http://www.esenias.org</a>
Canadian Aquatic Invasive Species Network (CAISN)	<a href="http://www.caisn.ca">http://www.caisn.ca</a>
Ellenic Network on Aquatic Invasive Species (ELNAIS)	<a href="http://elnais.hcmr.gr">http://elnais.hcmr.gr</a>

*International Working Groups*

IUCN SSC Invasive Species Specialist Group (ISSG)	<a href="http://www.issg.org">http://www.issg.org</a>
SIL Working Group on Aquatic Invasive Species (WGAIS)	<a href="http://limnology.org/members/sil-working-groups/">http://limnology.org/members/sil-working-groups/</a>
European Group on Biological Invasions (NEOBIOTA)	<a href="http://www.neobiota.eu">http://www.neobiota.eu</a>
ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV)	<a href="http://www.ices.dk/community/groups/Pages/WGBOSV.aspx">http://www.ices.dk/community/groups/Pages/WGBOSV.aspx</a>
ICES Working Group on Introduction and Transfers of Marine Organisms (WGITMO)	<a href="http://www.ices.dk/community/groups/Pages/WGITMO.aspx">http://www.ices.dk/community/groups/Pages/WGITMO.aspx</a>

*Editorial Boards of International Scientific Journals*

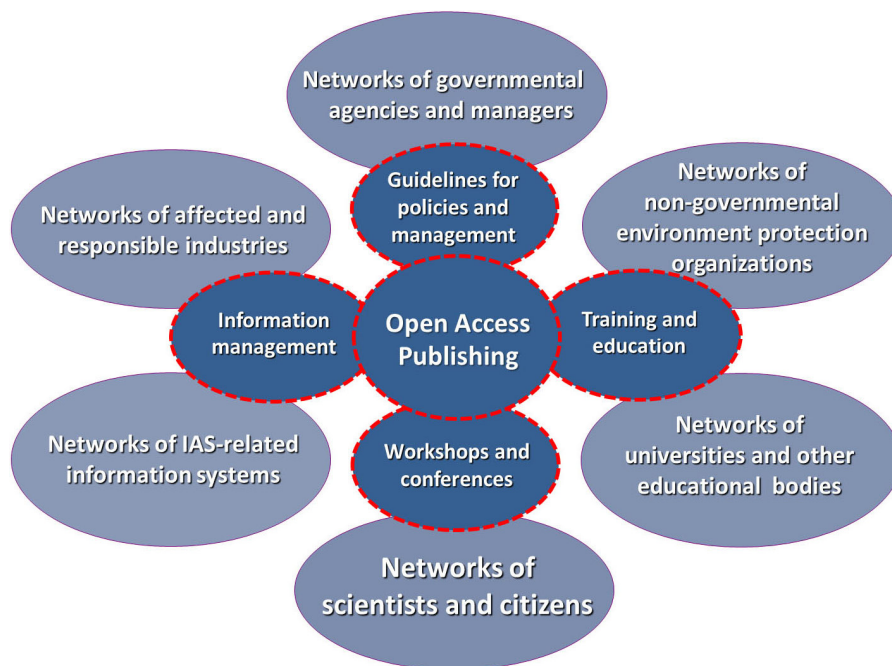
Aquatic Invasions (REABIC)	<a href="http://www.aquaticinvasions.net">http://www.aquaticinvasions.net</a>
BioControl (Springer)	<a href="http://www.springer.com/life+sciences/entomology/journal/10526/PSE">http://www.springer.com/life+sciences/entomology/journal/10526/PSE</a>
BioInvasions Records (REABIC)	<a href="http://www.reabic.net/journals/bir/">http://www.reabic.net/journals/bir/</a>
Biological Invasions (Springer)	<a href="http://www.springer.com/life+sciences/ecology/journal/10530/PSE">http://www.springer.com/life+sciences/ecology/journal/10530/PSE</a>
Hydrobiologia (Springer)	<a href="http://www.springer.com/life+sciences/ecology/journal/10750/PSE">http://www.springer.com/life+sciences/ecology/journal/10750/PSE</a>
Management of Biological Invasions (REABIC)	<a href="http://www.reabic.net/journals/mbi/">http://www.reabic.net/journals/mbi/</a>
Mediterranean Marine Science (HCMR)	<a href="http://www.medit-mar-sc.net">http://www.medit-mar-sc.net</a>
NeoBiota (Pensoft)	<a href="http://neobiota.pensoft.net">http://neobiota.pensoft.net</a>

*Thematic International Conferences*

International Conference of Aquatic Invasive Species (ICAIS)	<a href="http://www.icais.org">http://www.icais.org</a>
International Conference on Marine Bioinvasions (ICMB)	<a href="http://www.marinebioinvasions.info">http://www.marinebioinvasions.info</a>
Freshwater Invasives – Networking for Strategy (FINS)	<a href="http://finsconference.eu">http://finsconference.eu</a>
International Invasive Sea Squirt Conference (IISSC)	<a href="http://www.who.edu/main/sea-squirt-conference-v">http://www.who.edu/main/sea-squirt-conference-v</a>
9 <sup>th</sup> International Conference on Biological Invasions (NEOBIOTA 2016)	<a href="http://www.neobiota2016.org">http://www.neobiota2016.org</a>

*Databases and Information Platforms*

Global Invasive Species Database (GISD)	<a href="http://www.iucngisd.org/gisd/">http://www.iucngisd.org/gisd/</a>
Global Invasive Alien Species Information Partnership (GIASIPartnership)	<a href="http://giasipartnership.myspecies.info">http://giasipartnership.myspecies.info</a>
World Register of Introduced Marine Species (WRIMS)	<a href="http://www.marinespecies.org/introduced/">http://www.marinespecies.org/introduced/</a>
Global Biodiversity Information Facility (GBIF)	<a href="http://www.gbif.org">http://www.gbif.org</a>
Delivering Alien Invasive Species Inventories for Europe (DAISIE)	<a href="http://www.europe-aliens.org">http://www.europe-aliens.org</a>
European Alien Species Information Network (EASIN) database	<a href="http://easin.jrc.ec.europa.eu">http://easin.jrc.ec.europa.eu</a>
E-Science European Infrastructure for Biodiversity and Ecosystem Research (LifeWatch)	<a href="http://www.lifewatch.eu">http://www.lifewatch.eu</a>
Regional Euro-Asian Biological Invasions Centre (REABIC)	<a href="http://www.reabic.net">http://www.reabic.net</a>
AquaNIS database	<a href="http://www.corpi.ku.lt/databases/index.php/aquanis/">http://www.corpi.ku.lt/databases/index.php/aquanis/</a>
Nonindigenous Aquatic Species (NAS) database	<a href="http://nas.er.usgs.gov">http://nas.er.usgs.gov</a>
The Belgian Biodiversity Platform	<a href="http://www.biodiversity.be">http://www.biodiversity.be</a>



**Figure 2.** INVASIVESNET services for networks, with open access publishing as a core linking element.

### Our Mission

To facilitate a greater understanding and management of biological invasions by creating a global sustainable **network of networks** of all interested and affected stakeholders for development and effective exchange of open high quality knowledge and open data on invasive species

### Our Objectives

1. Develop and deliver high quality open knowledge and open data on biological invasions and IAS to all stakeholders globally.
2. Develop technical tools and cyberinfrastructure for the collection, management and dissemination of data and information on IAS to a global audience.
3. Create an effective communication platform on IAS-related issues for all interested stakeholders.
4. Support and promote international meetings and workshops on IAS.
5. Support and promote education, outreach and training on IAS science and management.
6. Support and promote effective citizen science related initiatives on IAS.
7. Collaborate with industries and companies and other stakeholders to develop and facilitate effective solutions for IAS-related issues.
8. Suggest how international legislation on IAS, namely the targeted Convention on Biological Diversity decisions and other relevant international agreements, can be implemented effectively based on solid scientific evidence.
9. Develop uniform guiding principles among stakeholders, based on solid and transparent IAS scientific criteria and advice from practitioners, managers, decision makers and policy makers.
10. Establish protocols and agreements with governments, agencies and private industries for data and knowledge publication, including online databases and journals.

Facilitation of the development and delivery of high quality open knowledge and open data on biological invasions and alien species to all stakeholders globally will be a priority objective of the association. The latter will occur primarily via the publication of thematic open access journals (associated with INVASIVESNET) and by knowledge provision and editing of existing open databases on IAS. The association will facilitate free access to results of scientific research in the areas of biological

invasions and invasive species globally, and, specifically, will encourage open access publications by scientists and other data holders. This is very much in line with the principles of the EU council on the transition towards an open science system (Council of the EU 9526/16). INVASIVESNET will also work on development of relevant funding infrastructure to support open access publications on IAS, and will work with commercial publishers to ensure free access to all IAS-related research and data published in their journals and books in the long-term.

### Legal status and Administration

INVASIVESNET will be a not-for-profit non-governmental international organization (open professional association). An International Council and Board representing major international thematic working groups and networks will be formed and will draft founding documents and lead the legal formation of the association. The first governing bodies of the association will be constituted from volunteers among the founding individuals and organizations. Eventually a small but agile secretariat will be formed to carry out administrative tasks. Different options for INVASIVESNET membership may be offered, such as organizational and individual, and membership fees will constitute the main funding stream for the association (e.g., <http://www.iufro.org>). Additional INVASIVESNET sponsorship may also be sought via individuals, organizations, through provision of services, or through crowdsourcing options.

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### Disclaimer

Authors of this paper, except for USGS authors Simpson and Fuller, represent their own independent viewpoint and not necessarily the views of the organization(s) that they represent. The USGS is exempt from this disclaimer.

### References

- Adriaens T, Sutton-Croft M, Owen K, Brosens D, van Valkenburg J, Kilbey D, Groom Q, Ehmgig C, Thürkow F, Van Hende P, Schneider K (2015) Trying to engage the crowd in recording invasive alien species in Europe: experiences from two smartphone applications in northwest Europe. *Management of Biological Invasions* 6: 215–225, <http://dx.doi.org/10.3391/mbi.2015.6.2.12>
- AquaNIS. Editorial Board (2015) Information system on Aquatic Non-Indigenous and Cryptogenic Species. World Wide Web electronic publication. <http://www.corpi.ku.lt/databases/aquanis>. Version 2.36+ (accessed 23 April 2016)
- Bellard C, Thuiller W, Leroy B, Genovesi P, Bakkenes M, Courchamp F (2013) Will climate change promote future invasions? *Global Change Biology* 19: 3740–3748, <http://dx.doi.org/10.1111/gcb.12344>
- Bellard C, Cassey P, Blackburn TM (2016) Alien species as a driver of recent extinctions. *Biology Letters* (in press), <http://dx.doi.org/10.1098/rsbl.2015.0623>
- Bouchout Declaration (2014) Bouchout Declaration on Open Biodiversity Knowledge Management. <http://bouchoutdeclaration.org> (accessed 23 April 2016)
- Caffrey JM, Baars, J-R, Barbour JH, Boets P, Boon P, Davenport K, Dick JTA, Early J, Edsman L, Gallagher C, Gross J, Heinimaa P, Horrill C, Hudin S, Hulme PE, Hynes S, MacIsaac HJ, McLoone P, Millane M, Moen TL, Moore N, Newman J, O'Conchuir R, O'Farrell M, O'Flynn C, Oidtmann B, Renals T, Ricciardi A, Roy H, Shaw R, Weyl O, Williams F, Lucy FE (2014) Tackling Invasive Alien Species in Europe: the top 20 issues. *Management of Biological Invasions* 5: 1–20, <http://dx.doi.org/10.3391/mbi.2014.5.1.01>
- Campbell ML (2013) The pointy end of the stick: managing biological invasions. *Management of Biological Invasions* 4: 1–2, <http://dx.doi.org/10.3391/mbi.2013.4.1.01>
- Canning-Clode J (ed) (2016) Biological Invasions in Changing Ecosystems: Vectors, Ecological Impacts, Management and Predictions. De Gruyter Open, 474 pp
- CBD (2002) COP 6 Decision V/23. Alien species that threaten ecosystems, habitats or species. Interim guiding principles for the prevention, introduction and mitigation of impacts of alien species. Sixth Ordinary Meeting of the Conference of the Parties to the Convention on Biological Diversity, 7–19 April 2002, The Hague, Netherlands, <https://www.cbd.int/decision/cop/?id=7197> (accessed 11 January 2016)
- CBD (2010) Aichi Biodiversity Target 9 of the Strategic Plan for Biodiversity 2011–2020. Tenth meeting of the Conference of the Parties to the Convention on Biological Diversity, 18–29 October 2010, Nagoya, Aichi Prefecture, Japan, <https://www.cbd.int/sp/targets/rationale/target-9/> (accessed 8 March 2016)
- CBD (2016) Convention on Biological Diversity, Programme of Work on Invasive Alien Species, <https://www.cbd.int/invasive/> (accessed 11 January 2016)
- Cliff N, Campbell ML (2012) Perception as a tool to inform aquatic biosecurity risk assessments. *Aquatic Invasions* 7: 387–404, <http://dx.doi.org/10.3391/ai.2012.7.3.010>
- Conn DB (2014) Aquatic invasive species and emerging infectious disease threats: A One Health perspective. *Aquatic Invasions* 9: 383–390, <http://dx.doi.org/10.3391/ai.2014.9.3.12>
- Costello MJ, Appeltans W, Bailly N, Berendsohn WG, de Jong Y, Edwards M, Froese R, Huettmann F, Los W, Mees J, Segers H, Bisby FA (2014) Strategies for the sustainability of online open-access biodiversity databases. *Biological Conservation* 173: 155–165, <http://dx.doi.org/10.1016/j.biocon.2013.07.042>
- Council of the European Union (2016) The transition towards an Open Science system—Council conclusions (adopted on 27/05/2016). General Secretariat of the Council. Brussels 9526/16

- Council of the European Union (2016) Competitiveness (Internal Market, Industry, Research and Space). 3470th Council meeting. Outcomes of the meeting. Brussels 9357/16 (provisional version)
- Crall AW, Newman GW, Jarnevich CS, Stohlgren TJ, Waller DM, Graham J (2010) Improving and integrating data on invasive species collected by citizen scientists. *Biological Invasions* 12: 3419–3428, <http://dx.doi.org/10.1007/s10530-010-9740-9>
- Crall AW, Jarnevich CS, Young NE, Panke BJ, Renz M, Stohlgren TJ (2015) Citizen science contributes to our knowledge of invasive plant species distributions. *Biological Invasions* 17: 2415–2427, <http://dx.doi.org/10.1007/s10530-015-0885-4>
- DAISIE (2016) Delivering Alien Invasive Species Inventories for Europe database (DAISIE), <http://www.europe-alien.org> (accessed 12 March 2016)
- Daume S (2016) Mining Twitter to monitor Invasive Alien Species—An analytical framework and sample information topologies. *Ecological Informatics* 31: 70–82
- Downs A (1972) Up and down with ecology—the “issue-attention cycle”. *National Affairs* 28: 38–50
- Esler KJ, Prozesky H, Sharma GP, McGeoch M (2010) How wide is the “knowing-doing” gap in invasion biology? *Biological Invasions* 12: 4065–4075, <http://dx.doi.org/10.1007/s10530-010-9812-x>
- Essl F, Bacher S, Blackburn T, Booy O, Brundu G, Brunel S, Cardoso AC, Eschen R, Gallardo B, Galil B, García-Berthou E, Genovesi P, Groom Q, Harrower C, Hulme PE, Katsanevakis S, Kenis M, Kühn I, Kumschick S, Martinou AF, Nentwig W, O’Flynn C, Pagad S, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roques A, Roy HE, Scalera R, Schindler S, Seebens H, Vanderhoeven S, Vilà M, Wilson JRU, Zenetos A, Jeschke JM (2015) Crossing frontiers in tackling pathways of biological invasions. *BioScience* 65: 769–782, <http://dx.doi.org/10.1093/biosci/biv082>
- EU (2014) Regulation (EU) No 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species. *Official Journal of the European Union* L315: 35–55, [http://ec.europa.eu/environment/nature/invasivealien/index\\_en.htm](http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)
- Galil BS, Marchini A, Occhipinti-Ambrogi A, Minchin D, Narščius A, Ojaveer H, Olenin S (2014a) International arrivals: widespread bioinvasions in European seas. *Ethology Ecology & Evolution* 26: 152–171, <http://dx.doi.org/10.1080/03949370.2014.897651>
- Galil BS, Boero F, Campbell ML, Carlton JT, Cook E, Fraschetti S, Gollasch S, Hewitt CL, Jelmert A, Macpherson E, Marchini A, McKenzie C, Minchin D, Occhipinti-Ambrogi A, Ojaveer H, Olenin S, Piraino S, Ruiz G (2014b) “Double trouble”: The expansion of the Suez Canal and marine bioinvasions in the Mediterranean Sea. *Biological Invasions* 17: 973–976, <http://dx.doi.org/10.1007/s10530-014-0778-y>
- Galil BS, Marchini A, Occhipinti-Ambrogi A (2016) East is East and west is west? Management of marine bioinvasions in the Mediterranean Sea. *Estuarine, Coastal and Shelf Science* (in press), <http://dx.doi.org/10.1016/j.ecss.2015.12.021>
- Genovesi P, Carboneras C, Vila M, Walton P (2015) EU adopts innovative legislation on invasive species: a step towards a global response to biological invasions? *Biological Invasions* 17: 1307–1311, <http://dx.doi.org/10.1007/s10530-014-0817-8>
- GISD (2016) Global Invasive Species Database, <http://www.iucngisd.org/gisd/> (accessed 12 March 2016)
- GISIN (2016) The Global Invasive Species Information Network (GISIN), <http://www.gisin.org> (accessed 12 March 2016)
- GISP (2010) The Global Invasive Species Programme (GISP), <http://www.diversitas-international.org/activities/past-projects/global-invasive-species-programme-gisp> (accessed 12 March 2016)
- Groom QJ, Desmet P, Vanderhoeven S, Adriaens T (2015) The importance of open data for invasive alien species research, policy and management. *Management of Biological Invasions* 6: 119–125, <http://dx.doi.org/10.3391/mbi.2015.6.2.02>
- Heywood VH, Sharrock S (2013) European Code of Conduct for Botanic Gardens on Invasive Alien Species. Council of Europe, Strasbourg, Botanic Gardens Conservation International, Richmond, 61 pp
- IPBES (2016) Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, Work Programme Deliverable 3(b)(ii): Thematic assessment on invasive alien species and their control. <http://www.ipbes.net/work-programme/invasive-alien-species> (accessed 25 May 2016)
- IHR (2005) International Health Regulations (2005) (IHR) Second Edition. World Health Organization. WHO Press, Geneva, Switzerland. <http://www.who.int/ihr/9789241596664/en/> (accessed 21 April 2016)
- Katsanevakis S, Genovesi P, Gaiji S, Hvid H, Roy H, Nunes A, Aguado F, Bogucarskis K, Debusscher B, Deriu I, Harrower C, Josefsson M, Lucy F, Marchini A, Richards G, Trichkova T, Vanderhoeven S, Zenetos A, Cardoso AC (2013) Implementing the European policies for alien species: networking, science, and partnership in a complex environment. *Management of Biological Invasions* 4: 3–6, <http://dx.doi.org/10.3391/mbi.2013.4.1.02>
- Katsanevakis S, Wallentinus I, Zenetos A, Leppäkoski E, Çinar ME, Öztürk B, Grabowski M, Golani D, Cardoso AC (2014) Impacts of marine invasive alien species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions* 9: 391–423, <http://dx.doi.org/10.3391/ai.2014.9.4.01>
- Kühn I, Kowarik I, Kollmann J, Starfinger U, Bacher S, Blackburn TM, Bustamante RO, Celesti-Grapow L, Chytrý M, Colautti RI, Essl F, Foxcroft LC, García-Berthou E, Gollasch S, Hierro J, Huffbauer RA, Hulme PE, Jarošík V, Jeschke JM, Karrer G, Mack RN, Molofsky J, Murray BR, Nentwig W, Osborne B, Pyšek P, Rabitsch W, Rejmánek M, Roques A, Shaw R, Sol D, van Kleunen M, Vilà M, von der Lippe M, Wolfe LM, Penev L (2011) Open minded and open access: introducing NeoBiota, a new peer-reviewed journal of biological invasions. *NeoBiota* 9: 1–12, <http://dx.doi.org/10.3897/neobiota.9.1835>
- Lenda M, Skórka P, Knops JMH, Moroi D, Sutherland WJ, Kuzewska K, Woyciechowski M (2014) Effect of the internet commerce on dispersal modes of invasive alien species. *PLoS ONE* 9, e99786, <http://dx.doi.org/10.1371/journal.pone.0099786>
- Lowry E, Rollinson EJ, Laybourn AJ, Scott TE, Aiello-Lammens ME, Gray SM, Mickle J, Gurevitch J (2013) Biological invasions: a field synopsis, systematic review, and database of the literature. *Ecology and Evolution* 3: 182–196, <http://dx.doi.org/10.1002/ece3.431>
- Lucy FE, Panov VE (2012) *BioInvasions Records*: A new international journal on biological invasions. *BioInvasions Records* 1: 1–4, <http://dx.doi.org/10.3391/bir.2012.1.1.01>
- Mazza G, Tricarico E, Genovesi P, Gherardi F (2014) Biological invaders are threats to human health: an overview. *Ethology, Ecology and Evolution* 26: 112–129, <http://dx.doi.org/10.1080/03949370.2013.863225>
- NIMPIS (National Introduced Marine Pest Information System) (2009) Web publication, <http://www.marinepests.gov.au/nimpis> (accessed 26 May 2016)
- NOBANIS (2016) The European Network on Invasive Alien Species. <http://www.NOBANIS.org> (accessed 23 April 2016)
- Ojaveer H, Galil BS, Campbell ML, Carlton JT, Canning-Clode J, Cook EJ, Davidson AD, Hewitt CL, Jelmert A, Marchini A, McKenzie CH, Minchin D, Occhipinti-Ambrogi A, Olenin S, Ruiz G (2015) Classification of non-indigenous species based on their impacts: considerations for application in marine management. *PLoS Biology* 13: e1002130, <http://dx.doi.org/10.1371/journal.pbio.1002130>
- Pagad S, Hayes K, Katsanevakis S, Costello MJ (2016) World Register of Introduced Marine Species (WRIMS). <http://www.marine-species.org/introduced> (accessed on 13 March 2016)



- Panov VE, Gollasch S, Lucy F (2011) Open-access journal *Aquatic Invasions*: An important part of the developing European information and early warning system on invasive alien species. *Aquatic Invasions* 6: 1–5, <http://dx.doi.org/10.3391/ai.2011.6.1.01>
- Pergl J, Genovesi P, Pyšek P (2016) Europe: Better management of alien species. *Nature* 531: 173, <http://dx.doi.org/10.1038/531173d>
- Pocock MJO, Roy HE, Fox R, Ellis WN, Botham M (2016) Citizen science and invasive alien species: Predicting the detection of the oak processionary moth *Thaumetopoea processionea* by moth recorders. *Biological Conservation* (in press), <http://dx.doi.org/10.1016/j.biocon.2016.04.010>
- Ricciardi A, Steiner WWM, Mack RN, Simberloff D (2000) Toward a global information system for invasive species. *BioScience* 50: 239–244, [http://dx.doi.org/10.1641/0006-3568\(2000\)050\[0239:TAGISF\]2.3.CO;2](http://dx.doi.org/10.1641/0006-3568(2000)050[0239:TAGISF]2.3.CO;2)
- Roux D, Rogers K, Biggs H, Ashton P, Sergeant A (2006) Bridging the science-management divide: moving from unidirectional knowledge to knowledge interfacing and sharing. *Ecology and Society* 11(1): 4
- Roy HE, Rorke SL, Beckmann B, Booy O, Botham MS, Brown PM, Harrower C, Noble D, Sewell J, Walker K (2015) The contribution of volunteer recorders to our understanding of biological invasions. *Biological Journal of the Linnean Society* 115: 678–689, <http://dx.doi.org/10.1111/bj.12518>
- Seebens H, Essl F, Dawson W, Fuentes N, Moser D, Pergl J, Pyšek P, van Kleunen M, Weber E, Winter M, Blasius B (2015) Global trade will accelerate plant invasions in emerging economies under climate change. *Global Change Biology* 21: 4128–4140, <http://dx.doi.org/10.1111/gcb.13021>
- Simpson A, Sellers E, Grosse A, Xie Y (2006) Essential elements of online information networks on invasive alien species. *Biological Invasions* 8: 1579–1587, <http://dx.doi.org/10.1007/s10530-005-5850-1>
- Sutherland WJ, Pullin AS, Dolman PM, Knight TM (2004) The need for evidence-based conservation. *Trends in Ecology & Evolution* 19: 305–308, <http://dx.doi.org/10.1016/j.tree.2004.03.018>
- Tollington S, Turbé A, Rabitsch W, Groombridge JJ, Scalera R, Essl F, Schwartz A (2015) Making the EU legislation on invasive species a conservation success. *Conservation Letters*, <http://dx.doi.org/10.1111/conl.12214>
- US Exec. Order No. 13642 (2013) Making Open and Machine Readable the New Default for Government Information. <https://www.gpo.gov/fdsys/pkg/FR-2013-05-14/pdf/2013-11533.pdf>
- van Kleunen M, Dawson W, Essl F, Pergl J, Winter M, Weber E, Krefl H, Weigelt P, Kartesz J, Nishino M, Antonova LA, Barcelona JF, Cabezas FJ, Cárdenas D, Cárdenas-Toro J, Castañón N, Chacón E, Chatelain C, Ebel AL, Figueiredo E, Fuentes N, Groom QJ, Henderson L, Inderjit, Kupriyanov A, Masciadri S, Meerman J, Morozova O, Moser D, Nickrent DL, Patzelt A, Pelsner PB, Baptiste MP, Poopath M, Schulze M, Seebens H, Shu W, Thomas J, Velayos M, Wieringa JJ, Pyšek P (2015) Global exchange and accumulation of non-native plants. *Nature* 525: 100–103, <http://dx.doi.org/10.1038/nature14910>
- Vanderhoeven S, Adriaens T, D'hondt B, Van Gossum H, Vandegehuchte M, Verreycken H, Cigar J, Branquart E (2015) A science-based approach to tackle invasive alien species in Belgium—the role of the ISEIA protocol and the Harmonia information system as decision support tools. *Management of Biological Invasions* 6: 197–208, <http://dx.doi.org/10.3391/mbi.2015.6.2.10>
- Vilà M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE & DAISIE (2010) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. *Frontiers in Ecology and the Environment* 8: 135–144, <http://dx.doi.org/10.1890/080083>
- Walther G-R, Roques A, Hulme PE, Sykes MT, Pyšek P, Kühn I, Zobel M, Bacher S, Botta-Dukát Z, Bugmann H, Czúcz B, Dauber J, Hickler T, Jarošík V, Kenis M, Klotz S, Minchin D, Moora M, Nentwig W, Ott J, Panov VE, Reineking B, Robinet C, Semchenko V, Solarz W, Thuiller W, Vilà M, Vohland K, Settele J (2009) Alien species in a warmer world: risks and opportunities. *Trends in Ecology & Evolution* 24: 686–693, <http://dx.doi.org/10.1016/j.tree.2009.06.008>
- Wenger E, McDermott R, Snyder W (2002) *Cultivating communities of practice: a guide to managing knowledge*. Boston Business School Press, Boston, Massachusetts, USA
- Young JC, Waylen KA, Sarkki S, Albon S, Bainbridge I, Balian E, Davidson J, Edwards D, Fairley R, Margerison C, McCreeken D, Owen R, Quine CP, Stewart-Ropper C, Thompson D, Tinch R, Van den Hove S, Watt A (2014) Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodiversity and Conservation* 23: 387–404, <http://dx.doi.org/10.1007/s10531-013-0607-0>