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REPORT ON ALIEN PATHOGENS AND PATHOGENS SPREAD BY INVASIVE ALIEN SPECIES IN EUROPE

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1. Summary

Invasive alien species (IAS) and emerging infectious diseases (EIDs) are known to interact as key drivers of biodiversity loss, encompassing species extinction and ecosystem change. As highlighted in the documents discussed in this note, a greater harmonisation and coordination between relevant policies pertaining to the two fields of IAS and EIDs would be key to ensure an effective management of the relevant threats. This would be particularly evident in relation to alien organisms acting as pathogens, as well as all those pathogens spread by IAS, which (may) have an impact on wild animals and plants. However, the two disciplines of IAS and EIDs are still lacking the required level of integration. Despite the current progress in science and policy in both fields, there are a number of knowledge and policy gaps, which may need to be addressed to ensure an appropriate and effective response action to effectively protect European wildlife.

The aim of this document is to provide Contracting Parties to the Bern Convention, namely their governments and national authorities, with an overview of the issues at stake in relation to alien pathogens and pathogens spread by IAS, as defined above. The main gaps in knowledge, science, policy and legislation (including at the EU level) - which may have an impact on the conservation objectives set by the Bern Convention - are described and discussed. This overview should set the basis for a larger discussion in the relevant scientific bodies of the Bern Convention, on the conservation actions (including research priorities) and possible policy and legislative recommendations that could be promoted by the Bern Convention on the issue. This would also help Contracting Parties to address the requirements of the article 8(h) of the CBD[1] and achieving Aichi Biodiversity Target 9 associated with the Strategic Plan for Biodiversity 2011-2020 of the CBD[2].

2. Rationale and key definitions

Biological invasions concern the study of species that have been moved by humans to regions beyond their native range, and as such are termed alien species. Those alien species that cause negative effects on biodiversity, society or the economy are termed **invasive alien species (IAS)**. IAS include organisms that cause disease as well as organisms that act as disease vectors and hosts (for example, parasites).

Introduction of alien species with a risk of carrying pathogens and their biological invasions may therefore contribute substantially to the spread of **emerging infectious diseases (EIDs)**, which represent a major threat not only to humans, but also to biodiversity and ecosystem services. In this sense, EIDs may affect livestock and crops, and ultimately wildlife (in the broader sense i.e. encompassing both animals and plants living in the "wild", which is the specific focus of this document).

As defined by the World Health Organization, Regional Office for South-East Asia (2014) "*An emerging infectious disease is one that has appeared and affected a population for the first time, or has existed previously but is rapidly increasing, either in terms of the number of new cases within a population, or its spread to new geographical areas*". This definition is commonly used in human and animal health fields (Ogden et al. 2019) and is also applied to both cultivated and wild plants (Anderson et al. 2004).

The relation between IAS and EIDs has been discussed by several authors (see overview below). Reportedly, two key problems need to be addressed to ensure a greater integration between the two disciplines:

[1] Each Contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.
[2] https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf

1) Despite IAS being recognised as a significant source of pathogen "pollution" (see Daszak et al. 2001), the attention paid so far to the impact on biodiversity caused by alien pathogens and by pathogens spread by IAS seems not adequate (Roy et al. 2017, Roy et al. 2016).

2) Biological invasions may play a key role in relation to EIDs, and some IAS are traditionally considered part of EIDs studies (Ogden et al. 2019). However, to date, attention has largely focused on the impact on human health, cropping systems and livestock production. The spread of those alien pathogens affecting only wildlife (wild animals and plants), has received less attention despite the magnitude of their known and potential effects on native and endangered species, ecosystems, and ecosystem services (Anderson et al. 2004, Peeler et al. 2011; Fisher et al. 2012).

The relevant policy and legislation framework seem to reflect the gaps summarised above. Biological invasions are globally recognised as one of the main drivers of biodiversity loss, consequently there is increasing attention, through national, regional and global policies, to address the problem of IAS spreading into new regions. Also, the current policy and legislation regarding EIDs affecting human health, as well as the health of animals and plant of productive concern, appear quite advanced and articulated. But the policy and legislation focusing on those alien pathogens and pathogens spread by IAS specifically affecting wildlife seems affected by some prominent gaps.

3. Scope and aim

The aim of this document is to provide Contracting Parties to the Bern Convention of the Council of Europe (CoE), namely their governments and national authorities, with an overview of the issues at stake in relation to alien pathogens and pathogens spread by IAS. The main gaps in knowledge, science, policy and legislation (including at the EU level) - which may have an impact on the conservation objectives set by the Bern Convention - are described and discussed. Given the exploratory nature of this document and the complexity of the overall issue, it was not possible to analyse in detail all subjects used as examples. Following the same approach of other technical documents drafted by the Bern Convention in relation to IAS policy, the key statements discussed in the text are supported by a selection of examples and other cited references, which the reader should access directly for any additional information and/or clarifications. There are also a number of pending issues which would certainly require further investigations, including on overall scope and definitions, as well as regarding the actual relevance of topics and problems discussed. All such issues would ideally represent the focus of the proposed workshops and the other initiatives recommended as a follow up.

This overview should set the basis for a larger discussion in the relevant scientific bodies of the Bern Convention, on the conservation actions (including research priorities) and possible policy and legislative recommendations that could be promoted by the Bern Convention on the issue. This would also help Contracting Parties to address the requirements of the Aichi Target 9 of the CBD (Roy et al. 2017).

4. Alien pathogens and pathogens spread by IAS, an overview

IAS and EIDs having an impact on wildlife can interact in several different ways. Besides acting as pathogens themselves, there are IAS contributing to the transmission and invasion of pathogens by acting as hosts of parasites (either native or alien) which may also be vectors of either native or alien pathogens, in any possible combination. IAS can represent the natural habitat for the pathogen which is maintained and persists over time within them, and as such may act as reservoir. Additionally, there are IAS acting as facilitators of hosts and/or vectors of pathogens. As a consequence, IAS can have an impact as pathogens themselves or for their role in introducing new and unknown pathogens, altering the epidemiology of local pathogens (e.g. by introducing changes in the vector-host-parasite relationship), becoming reservoir hosts, and so increasing the disease risk for native populations of

wild animals and plants (see also Prenter et al. 2004, Dunn 2009). Both alien pathogens and their effect may be rather cryptic (Jaric et al. 2019). This is further complicated by the very dynamic nature of pathogens, which are known to (quickly) adapt, shift to novel hosts, undergo swift genetic changes either through natural selection or via hybridization, and possibly lead to the emergence of entirely new invasive pathogens, and even the evolution of new species, with the risk of major changes in pathogenicity, transmissibility, etc. (Jaric et al. 2019, Roy et al. 2017, Ricciardi et al. 2017, Jeschke et al. 2013, Hulme 2014, Stukenbrock 2012).

Threats posed by IAS and EIDs are both characterized by large uncertainties in timing, magnitude, and effects on species (Converse and Grant 2019). The impact of pathogens and disease spread as a consequence of biological invasions have been the object of several reviews. For example, Daszak et al. (2001) discussed the emergence of infectious diseases in wildlife and the role of anthropogenic environmental changes. The subtle and wide-ranging impacts of pathogens and parasites on biological invasions are discussed by Prenter et al. (2004) and Dunn (2009). Peeler et al. (2011), Gozlan (2017) and Oidtmann et al. (2011) provide a discussion of the disease emergence driven by IAS in aquatic species. Also, Adlard et al. (2015) published a review on EIDs affecting wildlife in freshwater and marine systems, while Yon et al. (2019) focused on a selection of species of greater concern. Reviews on the life-history traits that facilitate emergence of pathogens responsible for wildlife epidemics were also carried out, e.g. by Dobson and Foufopoulos (2001) and Lymbery et al. (2014). Such studies show that introductions of parasites with alien hosts occur over a wide range of parasite and host taxa and often involve parasites with complex life cycles that require an alternative host in the new locality. Pathogens with a direct life cycle, that lack intermediate stages and only require a single host species to complete their development, may persist in a wider range of environmental conditions. However, this seems equally probable for species with complex life cycles, e.g. producing resting stages (Solarz and Najberek 2017). Otherwise Wingfield et al. (2016) discussed the poor understanding of relationships between forest pathogens and their vectors, also for few well-studied examples. In fact, it seems that there is little information about wild-plant EIDs (compared to those of crop plant), suggesting that their impact on conservation is underestimated (Anderson et al. 2004).

Blackburn and Ewen (2017) offer an exhaustive review of the current state of the potential for parasites to be both drivers of, and passengers on, the success of translocated populations. Morand (2017) pointed out that the risks of disease introduction in invaded localities, or outbreaks of native diseases, are clearly dependent on the types of introduced and native pathogens, their ability to spill-over or spill-back, and the features of invaded localities (see also Kelly et al. 2009). Solarz and Najberek (2017) highlighted that alien species can act as hosts even if they fail to establish following introduction to new areas.

Moreover, alien pathogens and pathogens spread by IAS may interact with other driving factors, such as habitat loss, climate change, overexploitation, and environmental pollution to contribute to local and global extinctions (Smith et al. 2009). Smalling et al. (2019), in relation to amphibian diseases, discussed how the presence of multiple stressors can increase uncertainty, and how this can affect the assessment of model scenarios, and the identification of possible management options.

The impact of alien pathogens may extend beyond the host population to influence biological communities and ecosystem functioning (Dunn and Perkins 2012). For example, alien pathogens may have not only direct effects on their hosts, but also indirect effects on the species with which their hosts interact, therefore parasites can have indirect effects that propagate up through the trophic levels (Dunn et al. 2012). The spread of alien pathogens and pathogens spread by IAS in the invaded environment may have dramatic effects on native wildlife, i.e. by causing extinctions, which in turn may affect ecosystem functioning (Morand 2017). This may be explained, at least in part, through the enemy release hypothesis (Torchin and Mitchell 2004, Prenter et al. 2004, Dunn 2009, Dunn et al. 2012): when introduced into a new region, plants and animals generally escape most of their native parasites, while those that they accumulate in their novel region seem to amount to only a fraction of those that they have escaped, which may explain why some introduced species proliferate in their new

environment and become destructive invaders. However, as pointed out by Roy et al. (2011), empirical evidence for the role of the enemy release hypothesis in invasion success is generally lacking, hence further insight is required in relation to the effect of specific natural enemies on alien and native species and their ability to regulate populations.

On the contrary, it is possible that EIDs can suppress invaders and promote native species recovery (Flory et al. 2018) and so can be a precious ally to conservation biologist and wildlife managers, e.g. by acting as a biological control agent. Flory et al. (2018) argued that recognizing how pathogen accumulation may control some invader populations over the long term should be an integral part of invasion biology, as it is a potentially important factor shaping the dynamics of invaded communities.

5. Policy and legislation framework, an overview

The importance of the threat posed by IAS, and the importance of addressing EIDs (including in relation to IAS pathways), is reflected in a range of international, regional and national laws and agreements, through which a number of standards, guidelines, and recommendations are adopted and implemented. The objective of this section is to provide a brief summary (mostly excerpted from the relevant websites, brochures and key documents) of a selection of the more pertinent policy and legislation tools, including at the European and EU level.

5.1 The Bern Convention

A European Strategy on IAS was adopted by the Council of Europe (CoE) in 2003 (Genovesi and Shine 2004). The aim was to provide guidance to Bern Convention Parties on their efforts to identify and prioritise key actions to be implemented at the national and regional level to prevent and manage the introduction of IAS. The European Strategy on IAS includes a few explicit references to diseases, particularly in relation to the need to prevent disease incursions at source, and on arrival, through border control and quarantine measures. In addition to regularly monitor the implementation of the European Strategy on IAS, the Bern Convention has focussed its work on the identification and prioritisation of pathways and, with the support of a specialised "Group of experts on Invasive Alien Species", started preparing targeted Codes of Conduct[3] to address such key pathways. Measures to prevent pathogens being moved by alien species through the relevant pathways are directly or indirectly included in most codes, as appropriate.

The Bern Convention has also undertaken specific initiatives focusing on alien pathogens affecting native herpetofauna, namely the Recommendation No. 176 (2015) “on the prevention and control of the *Batrachochytrium salamandrivorans* chytrid fungus” and the Recommendation No. 197 (2017) “on biosafety measures for the prevention of the spread of amphibian and reptile species diseases”, adopted by the Standing Committee. Both recommendations were based on expert discussions and conclusions, expressed at meetings of the Convention’s Group of Experts on Amphibians and Reptile species. Additionally, on 5-8 December 2017, at the 37th meeting held in Strasbourg, the Standing

[3] So far the Standing Committee has endorsed Codes of Conduct on IAS and activities such as horticulture, zoos and aquaria, botanic gardens, hunting, pets or recreational fishing. Other codes are under development, including on plantation forestry and recreational boating. These codes of conduct are a useful tool for increasing awareness on the impact of IAS and federating the efforts of a wide range of stakeholders (including the business sector) through voluntary, sound and specific measures. The following recommendations refer to the codes formally adopted by the Standing Committee to the Bern convention:

- Recommendation No. 170 (2014) on the European Code of Conduct on Recreational Fishing and Invasive Alien Species;
- Recommendation No. 166 (2013) on the European Code of Conduct on Hunting and Invasive Alien Species;
- Recommendation No. 161 (2012) on the European Code of Conduct for Zoological Gardens and Aquaria on Invasive Alien Species;
- Recommendation No. 160 (2012) on the European Code of Conduct for Botanic Gardens on Invasive Alien Species;
- Recommendation No. 154 (2011) on the European Code of Conduct on Pets and Invasive Alien Species;
- Recommendation No. 134 (2008) on the European Code of Conduct on Horticulture and Invasive Alien Plants.

Committee instructed the Secretariat to seek opportunities to raise awareness among public at large on the issue linked to the spread of diseases.

The issue of alien pathogens and their negative impact on native herpetofauna has been the focus of the work of the Group of Experts on Amphibians and Reptile species in the past years, therefore at the meeting of the selected Group of Experts on Invasive Alien Species held in Rome in 2018[4], possible synergies with the Group of Experts on Amphibians and Reptiles were discussed. The Group of Experts on Invasive Alien Species recognised the importance to consider the issue of pathogens, and agreed that this is not only an issue for the environment sector (as it is also an issue of animal health and welfare dealt with by the agricultural sector) and does not only concern herpetofauna. The group recognised also that pathogens are by far the most important alien species and pose a threat for both wildlife and humans, and therefore action is needed to deal with the problem. On this regard, and taking into account the several facades on the issue, a key problem identified by the Group of Experts on Invasive Alien Species is the important knowledge gap on wildlife pathogens in general and the need for stronger cooperation and coordination of efforts between the amphibians' experts and IAS specialists. In addition, due to the high number of pathogens and species' groups concerned and to differences in terminology used by different experts, there are many misunderstandings on what is alien and what is endemic, how to deal with species becoming vectors, how reintroduced animals should be screened, etc. This would justify the need to work towards lifting these uncertainties and misunderstanding.

For all the reasons above, the following proposals have been made by the Group of Experts on Invasive Alien Species:

- The creation of a dedicated group of experts that can study the gaps in knowledge, science, legislation, etc. and clarify what action could be taken;
- A focus of the work of such a group can be, in particular on alien species carrying alien diseases; a review of existing guidance focussing on wildlife pathogens through introduced species;
- Ensure greater coordination and communication between the IAS specialists and the relevant Group of Experts working on herpetofauna, but also with other communities and sectors;
- Address the issue of the lack of awareness among scientists about potential risks of their research in spreading diseases, inform on risks and explain what to do and what not to.

5.2 The Convention on Biological Diversity

The international agreements related to IAS are primarily stipulated in Article 8h of the 1992 Convention on Biological Diversity (CBD), which states "*Each contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species*". The CBD articles are legally binding to Parties, which are expected to translate Article 8h into the national legislation. In 2002, at the 6th meeting of the CoP to the CBD, a specific Decision VI/23 was adopted. This Decision contains Guiding Principles in its annex to help Parties implement this requirement, and Parties, other Governments and relevant organizations were urged to promote and implement the Guiding Principles. This Decision also urges Parties, other governments and relevant organizations to develop IAS strategies and action plans at national and regional level and to promote and implement the CBD Guiding Principles. This includes the need to consider alien pathogens and pathogens spread by IAS[5]. At the 10th COP meeting, a Strategic Plan for Biodiversity with 20 headline targets for 2020, known as the Aichi Biodiversity Targets, was set out. In this context, Target 9 states: "*By 2020, invasive alien species and pathways*

[4] https://rm.coe.int/report-of-the-meeting-of-the-select-group-of-experts-on-invasive-alien/16808c776b

[5] See also definition here: https://www.cbd.int/idb/2009/about/what/ "*Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health. In particular, they impact adversely upon biodiversity, including decline or elimination of native species - through competition, predation, or transmission of pathogens - and the disruption of local ecosystems and ecosystem functions*"

are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment". This target requires the threats posed by alien pathogens and pathogens spread by IAS to be adequately addressed too. In 2018 at its 14th COP the Supplementary Voluntary Guidance for Avoiding Unintentional Introductions of Invasive Alien Species Associated with Trade in Live was adopted (Annex 1 to Decision 14/11). This guidance describes integrated processes for its implementation together with the guidance (Annex to Decision XII/16) and existing international standards set for the protection of biodiversity, and the health of animals (The OIE animal health codes and manuals), plants (International Standards for Phytosanitary Measures), and highly relevant to manage the pathways of introduction of pathogens associated with trade in live organisms.

5.3 The International Health Regulations and the World Health Organization

The International Health Regulations[6] (IHR) are international legal tools that are binding on 196 countries, including all Member States of the World Health Organization (WHO), an agency of the United Nations concerned with human health. The aim of IHR is to help the international community prevent and respond to public health risks that have the potential to cross borders and threaten people worldwide. The IHR require countries to report certain disease outbreaks and public health events to WHO. Building on the unique experience of WHO in global disease surveillance, alert and response, the IHR define the rights and obligations of countries to report public health events, and establish a number of procedures that WHO must follow in its work to uphold global public health security. WHO coordinates international outbreak response using resources from the Global Outbreak Alert and Response Network[7] (GOARN), which ensures that during outbreaks the right technical expertise and skills are on the ground where and when they are needed most. GOARN is a collaboration of existing institutions and networks, constantly alert and ready to respond. The network pools human and technical resources for rapid identification, confirmation and response to outbreaks of international importance.

5.4 The World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures

Under the World Trade Organization (WTO) Agreement of the Application of Sanitary and Phytosanitary Measures[8] (SPS), and the General Agreement on Tariffs and Trade (GATT), individual countries can restrict trade to protect animal or plant health or food safety (see Dunn and Hatcher 2015). The WTO-SPS Agreement provides a uniform framework for measures governing phytosanitary measures for human, plant and animal life or health. Sanitary and phytosanitary measures are defined as any measure applied:

a) to protect human, animal or plant life or health (within the Member's Territory) from the entry, establishment or spread of pests, diseases, disease carrying organisms;
b) to prevent or limit other damage (within the Member's Territory) from the entry, establishment or spread of pests.

Currently recognised international standards of relevance for the present document are those developed by the World Organisation for Animal Health and within the International Plant Protection Convention framework.

[6] https://www.who.int/topics/international_health_regulations/en/
[7] https://www.who.int/ihr/alert_and_response/outbreak-network/en/
[8] http://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

5.5 The World Organization for Animal Health

The World Organisation for Animal Health[9] (OIE) is the intergovernmental organisation responsible for animal health worldwide. The OIE is recognized by WTO as the international standard setting body for animal health, under the SPS Agreement. The OIE has a total of 182 Member Countries and maintains permanent relations with nearly 75 other international and regional organisations and has Regional and sub-regional Offices on every continent. The OIE maintains Animal Health Codes[10] and early warning systems to prevent the spread of notifiable diseases pathogenic to animals and humans through international trade in animals and to promote animal welfare. Such codes include guidelines regularly updated for import risk analysis as well as risk management measures applicable to specific diseases.

One of the formal obligations of OIE Member Countries is the submission of information on the relevant animal disease situation in a timely and transparent way. A single OIE list of notifiable terrestrial and aquatic animal diseases has been established for this purpose and, to accomplish its mandate in this respect, the OIE manages the World Animal Health Information System (WAHIS) interface. The OIE primary focus is on livestock pathogens but in the last years the focus has been progressively extended also to diseases affecting wildlife (for example, three highly invasive amphibian pathogens are currently listed). OIE recognises that "wildlife diseases may have a serious impact on livestock health and public health and can adversely affect wildlife conservation" and that "Disease surveillance in wildlife must be considered just as important as surveillance in domestic animals". Wildlife disease surveillance can be a useful and complementary component of human and animal disease surveillance, monitoring, prevention and control programmes, as well as conservation efforts (see OIE Guidelines for Wildlife Disease Surveillance: An Overview[11]). Therefore, a WAHIS-Wild Interface has been also developed, including information about non OIE-listed diseases in wildlife[12]. These diseases have not met the OIE's criteria to be listed (hence this should not have any impact on international trade of animals and their products), but the OIE's experts of the Working Group on wildlife diseases have selected them to be monitored, both because of their importance for wild animals and also for early warning purposes, in order to protect human and livestock health.

With the aim to inform and advise the OIE on all health problems relating to wild animals, a specific Working Group on Wildlife[13] was founded already in 1994. Among the various tasks this Working Group maintains global perspective and foresight on wildlife health and biodiversity and their interface with animal health and veterinary public health, including in relation to IAS. Moreover, it prepared recommendations and technical documents on the surveillance and control of important wildlife diseases[14].

5.6 The International Plant Protection Convention

The International Plant Protection Convention[15] (IPPC) is the intergovernmental organisation responsible for plant health worldwide. The IPPC is recognized by WTO as the international standard setting body for plant health, under the SPS Agreement. Its aim is to secure coordinated, effective action to prevent and to control the introduction and spread of pests of plants and plant products (pest

[9] http://www.oie.int
[10] the Terrestrial Animal Health Code http://www.oie.int/en/international-standard-setting/terrestrial-code/ and the Aquatic Animal Health Code http://www.oie.int/en/international-standard-setting/aquatic-code/
[11] http://www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/WGWildlife/OIE_Guidance_Wildlife_Surveillance_Feb2015.pdf
[12] http://www.oie.int/wahis_2/public/wahidwild.php/Diseaseinformation/popup/diseaselist
[13] http://www.oie.int/en/standard-setting/specialists-commissions-working-ad-hoc-groups/working-groups-reports/working-group-on-wildlife/
[14] see examples here http://www.oie.int/en/standard-setting/specialists-commissions-working-ad-hoc-groups/working-groups-reports/working-group-on-wildlife
[15] https://www.ippc.int/en/

is a broad enough term that covers also IAS threatening plants in the wild environment). The IPPC extends beyond the protection of cultivated plants to the protection of natural flora and plant products. It takes into consideration both direct and indirect damage by pests. It also covers vehicles, aircraft and vessels, containers, storage places, soil and other objects or material that can harbour or spread pests.

The IPPC provides a framework and a forum for international cooperation, harmonization and technical exchange between contracting parties. Its implementation involves collaboration by National Plant Protection Organizations (NPPOs) the official services established by governments to discharge the functions specified by the IPPC and Regional Plant Protection Organizations (RPPOs), which can act as coordinating bodies at a regional level to achieve the objectives of the IPPC. The IPPC Commission on Phytosanitary Measures has adopted a number of relevant International Standards for Phytosanitary Measures (ISPMs) with the objective to harmonise the measures to be taken at the national level. Pest risk assessment (PRA) schemes have been developed in line with the IPPC framework, hence conform to the ISPMs recognized by the WTO. Also, when developing or revising standards to address pathway and vector risks in pest risk analysis (PRA), the IPPC has explicitly addressed the risk of IAS impact on biodiversity.

5.7 The European and Mediterranean Plant Protection Organization

The European and Mediterranean Plant Protection Organization[16] (EPPO) is a RPPO within the framework of the IPPC, which develops regional phytosanitary measures, including a dedicated work programme and expert panel for invasive alien plants. This intergovernmental organization is responsible for cooperation in plant health within the Euro-Mediterranean region, and its objectives are to protect plants, by developing international strategies against the introduction and spread of pests which are a threat to agriculture, forestry and the environment, and by promoting safe and effective pest control methods. EPPO has produced and adopted a large number of Standards in the areas of plant protection products and plant quarantine, including Standards on Pest Risk Assessment, Pest Risk Management and on Environmental Risks of Biocontrol Agents. These Standards constitute recommendations that are addressed to the NPPOs of EPPO member countries. Furthermore, EPPO advises member Governments on the technical, administrative and legislative measures necessary to prevent the introduction and spread of pests and diseases of plants and plant products. Finally, EPPO promotes the exchange of information between its member countries by maintaining information services and databases on pests of plants, and by organizing many conferences and workshops.

5.8 The EU Regulation No. 1143/2014 on Invasive Alien Species

The EU Regulation on IAS[17] entered into force on 1st January 2015. This Regulation is based on the CBD Guiding Principles of prevention, prioritisation and coordination and seeks to address the problem of IAS in a comprehensive manner. The objective is to protect native biodiversity and ecosystem services, as well as to minimize and mitigate the human health or economic impacts that these species can have. The core of the system is an open "list of IAS of Union concern" for which a general ban from the EU, including introduction, transport, trade, keeping, breeding and release into the environment, is established (but the regulation also provides for a system of authorizations and permits to allow certain activities based on IAS). Not only article 7 restrictions apply, but also all other obligations, including notification and rapid eradication or management. The list is a dynamic tool which is being regularly updated by the EC through discussion with Member States, based on risk assessments which satisfy the conditions set out under Article 5(1) of the Regulation (e.g. see also Roy et al. 2019). The decision process basically relies on a Committee composed by representatives from Member States, and a "Scientific Forum" composed of representatives of the scientific community nominated by the Member States with the role of providing advice. The transmission of diseases is recognized as a threat posed by IAS to biodiversity and related ecosystem services, and as such is

[16] https://www.eppo.int
[17] http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

taken into account in the risk assessments. However, species acting as pathogens themselves do not qualify for listing. In fact, according to art. 2, this Regulation does not apply to:

- pathogens that cause animal diseases (for the purpose of the IAS Regulation, animal disease means the occurrence of infections and infestations in animals, caused by one or more pathogens transmissible to animals or to humans);
- harmful organisms listed in Annex I or Annex II to Directive 2000/29/EC, and harmful organisms for which measures have been adopted in accordance with Article 16(3) of that Directive.

This is because the IAS Regulation recognises that there are currently over 40 Union legislative acts on animal health which include provisions on animal diseases. Therefore, any new rules on IAS should be aligned with and not overlap with those legislative acts of the Union, and should not apply to the organisms targeted by those legislative acts.

The EU regulation on IAS includes some innovative pathways-related provisions, such as the provisions of art. 13, according to which Member States are required to adopt and implement action plans to address priority pathways (see on this regard the document made by the Bern Convention on Guidance for governments concerning IAS pathways action plan[18]). In this way alien pathogens and pathogens spread by IAS are likely to be addressed too.

5.9 The EU Animal Health policy and legislation

In March 2016, as a key output of the Animal Health Strategy 2007-2013 "Prevention is better than cure", the European Parliament and the Council adopted the Regulation on transmissible animal diseases[19] ("Animal Health Law" [20]), which will be applicable from 21 April 2021. This Regulation is about animal diseases that are transmissible to animals or humans. It provides for principles and rules for the prevention and control of such diseases in kept animals (i.e. animals under human control) and wild animals and animal products. More precisely, these rules consist of requirements for disease prevention and preparedness; disease awareness; biosecurity; traceability of animals and where necessary products thereof; intra-EU movements and entry into the EU of animals and animal products; surveillance; disease control and eradication; and emergency measures. If a disease is not listed for EU intervention, either the national public administration or the private agricultural or aquaculture sector or any other stakeholders (e.g. those who are concerned about wild animals) in the Member States can take proportionate measures and improve the health situation concerning that disease in their territory. However, the measures applied should respect the rules of the single market[21]. The Regulation also introduces a special chapter on non-commercial movements of pet animals. These new rules take over the rules from the existing Regulation (EU) No 576/2013 on the non-commercial movements of pet animals. However, there will be a 10-year transitional period.

The EU animal health policy[22] is the result of decades long development in the fight against transmissible animal diseases (often epidemics) and covers all animals in the EU kept for food, farming, sport, companionship, entertainment and in zoos. It also covers wild animals and animals used in research where there is a risk of them transmitting disease to other animals or to humans. It is also strongly linked to the international standards of the relevant standard setting body (OIE) and the EU's obligations under the SPS Agreement in the context of WTO.

The animal health conditions governing the placing on the market of aquaculture animals and products are defined in Council Directive 2006/88/EC. This Directive has been amended several times in order

[18] https://rm.coe.int/1680746339
[19] https://ec.europa.eu/food/animals/health/regulation_en
[20] Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law')
[21] https://ec.europa.eu/food/sites/food/files/animals/docs/ah_law_regulation-proposal_qanda.pdf
[22] https://ec.europa.eu/food/animals/health_en

to update the legislation to new situations and new scientific knowledge[23]. Because the animal health situation is not the same throughout the territory of the EU, the movement regulations are based on the concept of approved (disease free) zones and farms for non-exotic diseases listed in Part II of Annex IV to Directive 2006/88/EC. The Directive lays down the criteria and procedures for the granting, maintenance, suspension, restoration and withdrawal of approval of such zones and farms as well as certification requirements for movement into disease free zones/farms. It also contains rules governing import from non-EU countries.

The EU policy on the issue is very complex and articulated. Many other tools are currently available, but their description goes beyond the purpose of the present document. For example, there is some legislation aimed at governing the organization of veterinary checks on animals entering the EC, like Council Directive 97/78/EC and Council Directive 91/496/EEC, which lay down provisions that allow EU countries or the Commission to take immediate action in the event that an outbreak of a disease presents a serious threat to animal or public health.

It is worth mentioning also the Commission Implementing Decision 2018/320, through which specific animal health protection measures for import and intra-EU movements of salamanders in relation to the fungus *Batrachochytrium salamandrivorans* (*Bsal*) were undertaken, although they should apply only temporarily (at least until 31 December 2019), until more information will be available to supplement the current knowledge on *Bsal* (EFSA Panel on Animal Health and Welfare et al. 2018).

5.10 The EU Plant Health Law

The core of the EU policy and legislation in relation to plant health is Council Directive 2000/29/EC[24], as amended. The general principles of this directive are based upon provisions laid down by the IPPC. The aim is to protect crops, fruits, vegetables, flowers, ornamentals and forests from harmful pests and diseases (harmful organisms) by preventing their introduction into the EU or their spread within the EU. In accordance to the legislation, if a harmful organism is found in the EU, the country concerned must:

- notify the Commission and the other EU countries;
- eradicate or prevent the spread of the harmful organism.

If there is an imminent danger of introduction or spread of a harmful organism, an EU country should state the control measures it would like to see taken and may temporarily take additional national control measures. Temporary (emergency) control measures may be taken by the EU in certain conditions, and new EU measures to control the introduction and spread of the harmful organisms may be introduced.

Directive 2000/29/EC, as last amended by Implementing Directive (EU) 2019/523, will be repealed on 14 December 2019 and will be replaced by Regulation (EU) 2016/2031 of the European Parliament and of the Council concerning protective measures against pests of plants.

5.11 One Health

The "One Health"[25] concept, introduced at the beginning of the 2000s, summarises the idea that human health and animal health (including both domestic animals and wildlife) are interdependent and bound to the health of the ecosystems in which they exist. This takes into account the increasing globalization of health risks and the importance of the human–animal–ecosystem interface in the evolution and emergence of pathogens (Destoumieux-Garzón et al. 2018). One Health concept has

[23] See here for details https://ec.europa.eu/food/animals/animalproducts/aquaculture_en
[24] https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation_en
[25] http://www.oie.int/en/for-the-media/onehealth/

evolved, which postulates that reactionary or preparatory responses to threats to human well-being demand holistic, transdisciplinary approaches encompassing all three human–animal–ecosystem components, including medical and veterinary practitioners and collaborators in ecosystem health (Ogden et al. 2019).

Putting the One Health vision into practice has been facilitated by a formal alliance on this topic between WHO, OIE and the Food and Agriculture Organization (FAO), which have been working together for years to address risks at the human-animal-ecosystems interface. The FAO/OIE/WHO Tripartite Concept Note[26] of 2010 has formalised this multi-sectoral collaboration and represents the key reference on the shared responsibilities for addressing health risks. As stressed by Ogden et al. (2019) public health organizations around the world are increasingly adopting the One Health approach to make their responses to infectious diseases more effective.

6. Main gaps or constraints

The capacity of Contracting Parties to the Bern Convention to effectively protect wildlife from the threat currently posed by alien pathogens and pathogens spread by IAS (see Langwig et al. 2015), is likely to be limited by the incomplete knowledge and the very fragmented and dynamic policy and legislation framework on the issue. Due to phenomena such as invasion debt, increasing current invasion trends, and increase of the species pool reached by vectors, the number of introduced species will increase further and preventive management needs to be strengthened (for further details see Schindler et al. 2018 and references therein). On the other hand, the fact that most forecasts of the risk of EIDs have largely neglected the potential role of IAS highlights a major gap in global preparedness against the relevant threat (Hulme 2014). Ongoing global changes and global trades may even escalate new threats (Morand 2017) and pose new challenges for IAS management (Schindler et al. 2018, Adlard et al. 2015). As remarked by Scheele et al. (2019b) global trade has recreated a functional Pangaea for infectious diseases in wildlife, with far reaching impacts on biodiversity, livestock, and human health. For example, wildlife trade is deemed to play a key role in amphibian EIDs (see O'Hanlon et al. 2018, Martel et al. 2014). The underlying factors driving wildlife EIDs are predominantly ecological and almost entirely the product of environmental change caused by humans (Daszak et al. 2001, Schindler et al. 2018). Climate change, land use, and transport vectors may interact in complex ways to determine the spread and impact of alien pathogens and IAS contributing to the spread of pathogens (Crowl et al. 2008, Ricciardi et al. 2017) but baseline data necessary to detect and verify such changes may be not available (Van Hemert et al. 2014, Yon et al. 2019). The increasing movements of humans and other species because of climate change and other factors could result in the sudden emergence of disease outbreaks, including new diseases and in new locations. Understanding the interactions of IAS, disease vectors, and pathogens with other drivers of ecosystem change is not only critical to human health and economic well-being (Crowl et al. 2008) but also to animal and plant health, and ultimately to wildlife.

6.1 Priority research areas

The identification of knowledge gaps, research priorities, and policy recommendations with respect to alien pathogens threatening wildlife within natural and seminatural systems, has been the focus of a workshop held in Wallingford (UK) on 18–19 March 2015 (see Roy et al. 2017). The objective of the workshop was to help scientists, wildlife managers, and conservation practitioners bridge the knowledge gaps, which affect the opportunities to take action, and hence inform policy and decision makers. For this purpose, 39 experts from 13 European countries, with expertise ranging from conservation biology and invasion ecology to wildlife epidemiology and disease management, gathered together on a collaborative horizon scanning exercise. The result was the definition of the following 10 key areas identified for research and action:

[26] http://www.oie.int/fileadmin/Home/eng/Current_Scientific_Issues/docs/pdf/FINAL_CONCEPT_NOTE_Hanoi.pdf

1. Baseline information needed on taxa in source range with potential to be pathogenic;
2. Improved understanding of pathway dynamics and networks leading to introduction;
3. Baseline information needed on distribution and population dynamics of pathogens, hosts, and vectors;
4. Improved understanding of life history traits of pathogens;
5. Need for predictive approaches to understanding pathogen host specificity and potential for host shift;
6. Need for predictive approaches to understanding potential for ecological and evolutionary adaptation in the invaded range;
7. Improved understanding of transmission dynamics in the environmental conditions in the invaded range;
8. Baseline information needed on recipient population, community, and ecosystem dynamics;
9. Improved understanding of distribution, abundance, and population dynamics of pathogens, vectors, and hosts in the invaded range;
10. Improved understanding of pathogenicity and virulence in hosts from the invaded range.

There are many other crucial questions about epidemiology and control strategies, particularly on the need for a better understanding of the parasite-vector-host trio and the environmental, climatic and socioeconomic factors involved (Capizzi et al. 2018). The various changes in the vector-host-parasite relationships may in fact influence invasion success and impact (see example by Solarz and Najberek 2017), and this would require careful investigation.

The development of interdisciplinary capacity, expertise and coordination to identify and manage threats was seen as critical to address the discussed knowledge and policy gaps (Adlard et al. 2015, Roy et al. 2017). For this reason, several authors urged the need of increased collaborations between invasion scientists, wildlife ecologists, conservation biologists, environmental biologists, disease ecologists, epidemiologists, veterinarians and medical scientists, medical microbiologists and related disciplines on modelling, risk assessment, monitoring and management (Daszak et al. 2001, Ogden et al. 2019, Schindler et al. 2018).

Given the tight linkage between IAS risks and the closer integration of the world economic system, the best strategy for dealing with the problem involves global coordination and cooperation, both to internalize what are potentially major externalities of world trade and to address the provision of a global public good (Perrings et al. 2010). Partnerships with competent authorities that monitor the spread and impacts of IAS and related pathogens would be critical in developing the required data and research network that can facilitate a full understanding of the resulting effects on ecosystems and society (Crowl et al. 2008). However, communication between scientists, managers and policy makers from different fields is often complicated by different perspectives and terminologies (Jeschke et al. 2013, Lymbery et al. 2014). This difference may be not trivial, as it may affect the ability to prevent or manage the transmission of pathogens and the emergence of epidemics.

6.2 Gaps in policy and legislation, including EU one

Roy et al. (2017) argued that the threats posed by alien pathogens to endangered species, ecosystems, and ecosystem services should receive greater attention through legislation, policy, and management. A better harmonisation of the policy and legislation concerning IAS and EIDs would also be beneficial to ensure a more effective response action. Also Dunn and Hatcher (2015) called for an international policy acknowledging the strong links between the IAS and EIDs risk. However, this would require some constraints to be adequately addressed. The policy and legislation to control IAS and EIDs, depends on the specific measures adopted at the national level, which in turn are developed in compliance to the policies and agreements discussed above. A main shortcoming is that the existing policies focus mainly on animals and plants of economic importance and often have little relevance to alien pathogens that affect wildlife (Roy et al. 2017). Therefore, in contrast with international policy on EIDs of humans and managed animals and plants, most IAS and related pathogens of wildlife (that

do not have direct human medical or economic impact) are likely to fall between the gaps of the main regulatory bodies (Dunn and Hatcher 2015, Roy et al. 2017).
Apparently the policy and legislation on IAS and wildlife pathogens is mostly fragmented, and the lack of international cooperation, coupled with unclear mandatory rules, may lead individual parties to minimize their proactive involvement and delay the necessary response actions (Dunn and Hatcher 2015, Roy et al. 2017), with an obvious impact on native wildlife. Another related constraint seems to be the difficulty to identify the responsible actors. For example, Beneult et al. (2014) pointed out the difficulties to know the government structure in charge of wildlife.

The uncoordinated and extemporary nature of the response, if any, to EIDs in wildlife, is a clear consequence of these apparent policy and legislation gaps (Roy et al. 2017). The issue is well illustrated by the case of the *Bsal*. For example, the Bern Convention recently approved recommendation No. 176 (2015) to "Impose immediate restrictions on salamander and newt trade". *Bsal* was listed in OIE Aquatic Animal Health Code in May 2017. The EU reacted promptly, and in the same year financed a 900,000 euro study aimed at "Mitigating a new infectious disease in salamanders to counteract the loss of European biodiversity". Successively, animal health protection measures were undertaken, e.g. the Commission Implementing Decision 2018/320 discussed above. Some authors noted that there are omissions that weaken this regulation's relevance, for example, the non-inclusion of anurans, which can act as *Bsal* carriers and not regulating animal traffic between private individuals (Thomas et al. 2019). However, while it is too early to assess the impact of such measures, it is evident that the time and resources needed to address a single alien pathogen were relatively high and would not allow to effectively address the multitude of alien pathogens and pathogens spread by IAS which may emerge in the future.

Hopefully, this amphibian disease - likewise many other ones - will be listed in the EU Regulation 2016/429 (Animal Health Law) on transmissible animal diseases. This legislation provides a legal basis to tackle diseases that could have a significant negative impact on biodiversity (through biosecurity, contingency planning, surveillance, and eradication) but it will be applicable only from 21 April 2021, therefore it is not possible to discuss the impact and efficacy of this tool for the time being.

6.3 Management implications

The gaps in knowledge, science, policy and legislation regarding alien pathogens and pathogens spread by IAS affecting wildlife, have some evident implications on the possibility to manage the problem in a proper and effective way. Dunn and Hatcher (2015) summarised the many parallels in the strategies needed to control the spread of IAS and EIDs, which are reflected in policy and legislation. An example is the importance of biosecurity precautions to prevent the introduction or spread of harmful species, which is common to both biological invasion and disease emergence policy (Dunn and Hatcher 2015). Timely measures to prevent introduction and establishment of alien pathogens (e.g. by implementing actions in relation to relevant pathways) would be more cost-effective than reactive measures to halt spread and manage disease epidemics following arrival (Roy et al. 2017, Langwig et al. 2015, Dunn and Hatcher 2015). But as noted by Grant et al. (2017), despite calls for improved responses to EIDs in wildlife, management is seldom considered until a disease is detected in affected populations. Based on the example of *Bsal*, they discussed how decision analysis may support policy makers and wildlife managers to improve proactive (pre-emergence) strategies and deal more effectively with the uncertainty which characterizes wildlife disease management. In relation to amphibian chytridiomycosis, other authors pointed out that although high-quality science is accumulating, often with important implications for mitigation, the literature leaves the challenge of imagining and developing solutions to managers (Canessa et al. 2019). This highlighted the need to stimulate and strengthen applied research that converts basic knowledge into information that is immediately relevant to managers.

Similarities between IAS and EIDs were discussed also by Daszak et al. (2001), Jeschke et al. (2013), Ogden et al. (2019), just to mention a few authors. However, Ogden et al. (2019) pointed out that the two fields of IAS and EIDs work mostly in parallel rather than in concert, despite the opportunities for synergies, and called for greater collaboration between the two fields. The general impression is that the role of biological invasions is rarely recognised in the field of EIDs, and this may lead to the inherent risk to overlook the right perspective needed to implement adequate management measures. For example, in the recent review by Yon et al. (2019) on pathogens with an impact on biodiversity and on species of conservation concern in Europe, the role of biological invasions is not explicitly recognised, despite the clear focus on alien pathogens or pathogens spread by IAS. The lack of adequate recognition of the role of biological invasions may have substantial implications on the possibility to effectively manage pathogens and their threat (see also Hulme 2014).

As pointed out by Ricciardi et al. (2017) a key problem in managing pathogen invasions is the limited ability to detect or identify emerging pathogens, owing to the lack of comprehensive global databases, the cryptic nature of some pathogen and their effect, and the potentially enormous number of undescribed taxa (which can remain obscure until a host die-off). To overcome this problem and obtain more reliable inference about pathogens, DiRenzo & Campbell Grant (2019) described a hierarchical modelling approach to account for imperfect detectability. This may lead to improved responsiveness, efficiency, and effectiveness of management interventions. Stage-specific goals and management actions that minimize disease impacts on wildlife, and the research required to implement them, are described also by Langwig et al. (2015).

In any case, it is clear that nowadays measures to control diseases in wildlife are highly constrained and eradication is rarely an option (Roy et al. 2017, Philibert et al. 2011). In such circumstances the return to the pre-invasion state may not be feasible, hence a certain degree of novelty in our ecosystems, including novel hosts and parasites, seems inevitable (Dunn and Hatcher 2015). Scheele et al. (2019a) suggest the use of an adaptive management framework to implement novel management approaches (namely, in the context of the global emergence of *Bd*). Other examples of novel management approaches are the recovery engine strategy described by Mendelson III et al. (2019) or the integrative approaches suggested by Destoumieux-Garzón et al. (2018). As suggested by Roy et al. (2017) a dedicated, coordinated, and comprehensive set of measures (e.g. inclusion of information on pathogens within alien species databases and sharing of such information), to be implemented from the global to the regional and local level, is clearly needed to ensure coordination and interdisciplinary approaches in terms of management policy (e.g. banning trade of potential vectors) and research policy (e.g. funding research projects on wildlife pathogens).

6.4 Building on the One Health initiative

The “One Health” concept seems going in the right direction toward the promotion of a collaborative global and interdisciplinary approach to understanding health risks for humans, animals and ecosystems. However, recent work has highlighted the need for more integrated approaches that also consider a more explicit focus on wildlife (Roy et al. 2017). Also, the role of biological invasions in the spread of EIDs is not explicitly recognised in “One Health” (although it recognises that risks increase with globalisation, climate change and changes in human behaviour, giving pathogens numerous opportunities to colonise new territories and evolve into new forms). Ogden et al. (2019) argued also that for sustainable development, biological invasions should be explicitly considered within One Health, as management goals and methods are the same as in the field of EIDs. Additionally, plants should deserve greater emphasis within the 'One Health' initiative (Fletcher et al. 2009).

Opportunities for immediate collaboration within a collaborative One Health approach are summarised by Ogden et al. (2019) as follows:

(1) Predictive modelling. Modelling of dispersal, introduction and spread of EIDs and IAS would be a relatively simple point of collaboration as the objectives are similar.
(2) Monitoring of EIDs and invasions. International scanning, as conducted for EIDs, could be readily applied to biological invasions.
(3) Management of invasions and EIDs. Given the transferable skill sets between those involved in EID and IAS management, and the possibilities for synergies between the fields, collaboration across the range of management activities could be very advantageous.

7. Recommendations

At the Bern Convention meeting held in Rome in 2018[27], the Group of Experts on Invasive Alien Species proposed the creation of a dedicated group of experts on wildlife pathogens that could study the gaps in knowledge, science, legislation, etc. and clarify what action could be taken to address the issue. It was established that a focus of the work of such a group could be, in particular, on alien species carrying alien pathogens, and could include the development of dedicated tools, e.g. a review of existing guidance focussing on wildlife pathogens spread through introduced species. Building on this, a selection of possible actions to be undertaken in relation to the discussed gaps in knowledge, policy and legislation, are suggested as a preliminary step for future action.

The focus of the next paragraphs is on the promotion of collaboration and interdisciplinarity across countries and fields of expertise, facilitated by dedicated networking activities. For this purpose, a number of complementary, not mutually exclusive, options are discussed, together with a number of priority issues to be addressed within the proposed networking activities. It is clear that the issue of alien pathogens and pathogens spread by IAS should not be considered in isolation from other threats to ecosystems, including i.e. climate changes. Furthermore, in principle the recommendations listed below should apply also to the field of conservation translocations, when concerning species moved outside their native range (see IUCN/SSC 2013).

7.1 Creation of a dedicated network

The creation of a network of concerned experts would be key to connect research initiatives across countries and fields of expertise, so to foster collaboration between groups and interdisciplinary approaches at the European level and beyond. This would allow biological invasion experts to liaise more closely to animal and plant health experts. There is a need to capitalise on experience from both fields. For example, in the field of animal and plant health there has been a lot of progress which is likely to be unknown by biologists. Building global interdisciplinary capacity, expertise, and coordination for wildlife pathogens is seen as critical on this regard (Roy et al. 2017). This could be achieved by organising a **horizontal working group on wildlife pathogens** under the umbrella of the Bern Convention.

7.2 Organisation of one or more dedicated workshops

Another possible approach could be the organisation of one or more **dedicated workshops** to assess actual and potential threats linked to the gaps in knowledge, policy and legislation and opportunities to prioritise action in this context. A priority issue to address would be the definition of the overall scope and the precise focus of any further initiative (for example regarding the taxa involved), but also on how to deal with the varied meanings of the terminology pertaining to the IAS and EIDs fields. Participation should be extended to all MS representatives, including from the EU, as well as any other relevant group set by the Bern Convention, and representatives from all key organisations (e.g. from OIE, IPPC, EPPO, FAO, CBD). A preliminary step in this direction could be a **preparatory meeting** of a selected group of experts (from both the Group of Experts on Invasive Alien Species and

[27] https://rm.coe.int/report-of-the-meeting-of-the-select-group-of-experts-on-invasive-alien/16808c776b

the Group of Experts on Amphibians and Reptile species) aimed at planning the details of the agenda and scope of the workshop.

7.3 Identification of key actors

The promotion of a **participatory approach** as inclusive as possible should be seen as critical for either the creation of dedicated network or the organisation of a workshop. For this purpose, it is fundamental to identify all concerned actors. Along with the key **experts** from both the IAS and EIDs fields, it would be important to identify the **authorities competent for dealing specifically with wildlife pathogens** (Roy et al. 2017) and ensure their involvement. For this purpose, it would be fundamental to liaise with other relevant **stakeholders** or networks. An example of relevant networks to involve is the European Wildlife Disease Association[28] (EWDA), which is a forum for the exchange of information on wildlife diseases and their management, aimed at providing opportunities for networking, collaborative research and training (see also Kuiken et al. 2011).

7.4 Circulation of questionnaires

As a preliminary approach to assess needs and expectancies in relation to any future activity on wildlife pathogens in relation alien species, could be the circulation of a dedicated **questionnaire** to the Contracting Parties to the Bern Convention and/or the chairs of the main working groups.

7.5 Clear formulation of research topics

There is a clear demand for an improved knowledge of the mechanisms and the impact which characterise the invasion by those alien pathogens and pathogens spread by IAS which affect wildlife (Roy et al. 2017, Morand 2017, Daszak et al. 2001). Any initiative aimed at the promotion of collaboration and interdisciplinarity (such as those listed above) would definitely be useful to allow a better formulation of the research topics which need to be addressed. Particular attention should be paid to research that may lead results useful to **support evidence-based conservation**, hence aimed at providing evidence readily available and relevant for decision-makers (see Canessa et al. 2019). An improved knowledge on alien pathogens and pathogens spread by IAS would certainly lead to a better understanding of the main management and policy measures to reduce the impact on wildlife by alien pathogens and pathogens spread by IAS. For example, the 10 research priorities identified by Roy et al. (2017) would not only increase understanding of the role of alien pathogens in invasion biology, but could also inform risk assessment frameworks and ultimately, One Health initiatives. This would also help MS and relevant stakeholders to **optimise results, avoid duplication of efforts and increase an effective allocation of resources**, i.e. by ensuring more focused use of financial resources, for example by making the most of the existing financial program, i.e. Horizon 2020, LIFE, COST and the likes.

7.6 Analysis of the current policy and legislation

A comprehensive **study on the current policy and legislation** relevant to all Bern Convention parties should be promoted, so to analyse and assess the actual gaps which prevent an effective management of the problem related to the invasion of alien pathogens and pathogens spread by IAS affecting wildlife. As a remark, it would be necessary to focus not only on current gaps in relation to existing policy and legislation, but also on constraints and barriers to the actual implementation of those existing measures which may allow to deal with the issue. This would be a fundamental step to assess the way ahead, and the pros and cons of any possible initiative (including whether any initiative should be undertaken at all). The need for a **global treaty**, as proposed by Roy et al. (2017), may be also considered, i.e. recognizing the complexities of alien pathogens while highlighting the need for coordinated action, alongside the mobilization of funding for research including dedicated national

[28] https://ewda.org

and international funding streams for rapid reaction to EIDs. The study should take into account the impact of current initiatives, including in relation to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services[29] (IPBES). The CBD and the **IPBES** should reinforce their participation to this strategic framework, developed by the FAO, WHO, and OIE (Rabitsch et al. 2017). As a side note, key Assessment of IAS is currently in progress within IPBES and a first draft is expected to be ready for open expert review in 2020.

7.7 Development of an action plan for wildlife pathogens

The study on legislation gaps would help define a dedicated **action plan** to deal with alien pathogens and pathogens spread by IAS (with an impact on wildlife). The generic action plan for the control of wildlife infections proposed by Beneult et al. (2014) could be used as a basis. That plan is based on European and International institutions guidelines and relies on the consultation and the coordination of different bodies concerned by wildlife management in Europe. It brings together legal surroundings, financial resources, governance system, material resources, procedures and methods required, the instructions of the coordination, cooperation and communication.

7.8 Identification of key management tools

There are many ways in which alien pathogens differ from other IAS, but there are also parallels including the ways in which they are introduced to a new region. Indeed, managing introduction pathways should be a priority for all IAS. This can be done by integrating consideration on the risk of invasion by alien pathogens and pathogens spread by IAS in both **risk assessment**s (and relevant **management annex**) and **pathways action plans** (Roy et al. 2017)**.**

The sound implementation of the **Codes of conduct** developed by the Bern Convention would contribute to prevent further introductions of alien pathogens through a number of pathways. For instance, many evidences exist about the contribution of international travels to the movement of alien pathogens and of pathogens spread by IAS (Anderson et al. 2014, Rumpf et al. 2018). The Code of conduct on international travels, which is addressed to a very wide variety of audience (from travel/tourism operators and relevant staff, to travellers, tourists, scientists and people in general) is an example of a tool which may have the double effect to prevent new incursions by both IAS and EIDs.

Disease Risk Analysis (DRA) protocols should be systematically associated to any movement of animals and plants, either within or between countries. This would be even crucial in case of disposal of alien species removed from the environment but kept alive in other places (e.g. transferred to rescue centre or other confined site, including semi-natural areas). In Mexico, the risks posed by ranavirus to wild endemic amphibians was assessed through the Pandora+ protocol[30] (D'hondt et al. 2014), a tool which originates from the Invasive Species Environmental Impact Assessment protocol (ISEIA) and is also used for risk assessments that support the listing of IAS within specific the relevant EU regulation (Saucedo et al. 2019). This is a perfect example of the synergies to be explored and promoted between the two fields of IAS and EIDs. Additionally, the identification of species-level traits that are predictors of invasion success for alien pathogens could be used to refine current pest risk assessment (PRA) schemes, as suggested in the case of forest pathogenic fungi in Europe (Philibert et al. 2011). Likewise, there are also detailed guidelines for conservation translocations that recognise the need to manage parasite transfer, and that prescribe **disease risk assessments** (IUCN/SSC 2013). However,

[29] The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services[29] (IPBES) is an independent intergovernmental body comprising more than 130 member Governments, which assesses the state of biodiversity and of the ecosystem services it provides to society, in response to requests from decision makers. The objective of IPBES is to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. Established by Governments in 2012, it provides policymakers with objective scientific assessments about the state of knowledge regarding the planet's biodiversity, ecosystems and the contributions they make to people, as well as the tools and methods to protect and sustainably use these vital natural assets. More info here: https://www.ipbes.net

[30] http://ias.biodiversity.be/protocols/form

these guidelines also stress that it is not possible (or necessarily desirable) to guarantee that translocated organisms are parasite-free (or will have non-target effects). The Scottish Code for Conservation Translocations[31] provides an example on how such guidelines have been applied.

It is also important to foster the inclusion of pathogens related to EIDs in relevant IAS **datasets** and increase awareness among policy and decision makers, wildlife managers, scientists, and citizens (Roy et al. 2017). Indeed, the development of an integrated network of research platforms and information exchange to identify hotspots of invasion or disease emergence, is key to ensure an early detection of pathogens and allow an in-depth understanding of IAS and EIDs (Crowl et al. 2008).

Citizen science could play a key role in relation to both the collection of data and on awareness raising. People can report new invasions, record phenological changes associated with invasions or disease outbreaks, and can participate in surveys, which may reveal long-term biotic change following species invasions and disease spread (Crowl et al. 2008). This would lead to an increased availability of high quality, interoperable data to inform science, policy and ultimately conservation. Some collaboration with already existing initiatives on this field could be envisaged, e.g. in relation to the COST Action Alien CSI[32].

Possibly, greater attention should be paid to the identification and development of tools and strategies needed to address the challenges that will result from the unavoidable "novelty in our ecosystems".

7.9 Increase awareness on the impact of wildlife pathogens

Increasing awareness among policy and decision makers, wildlife managers, scientists, and citizens is critical to prevent the introduction of alien pathogens and the movement of pathogens spread by IAS (Roy et al. 2017). This requires joint efforts in education and outreach to the public and decision makers (Schindler et al. 2018, Rabitsch et al. 2017).

[31] https://www.nature.scot/sites/default/files/Publication%202014%20-%20The%20Scottish%20Code%20for%20Conservation%20Translocations.pdf
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