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AD HOC TECHNICAL EXPERT GROUP
ON INVASIVE ALIEN SPECIES
Montreal, Canada, 2-4 December 2019

SYNTHESIS REPORT OF THE ONLINE FORUM ON INVASIVE ALIEN SPECIES

Note by the Executive Secretary

I. INTRODUCTION

1. The Conference of the Parties to the Convention of Biological Diversity (CBD) requested the Executive Secretary to continue to compile or develop and maintain decision support tools in a coordinated manner (decision XIII/13, para. 17) at its thirteenth meeting.

2. Further to the above decision, in paragraph 5 of decision 14/11, the Conference of the Parties decided to establish an Ad Hoc Technical Expert Group (AHTEG) with the terms of reference to ensure timely provision of advice on achieving Aichi Biodiversity Target 9, and requested the Executive Secretary to convene a moderated open online discussion forum to support the deliberations of the Ad Hoc Technical Expert Group.

3. In accordance with the Terms of Reference for the AHTEG annexed to the same decision, the AHTEG will address matters that are not covered by the assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Building on the work of the moderated online forum, and knowledge and experience accumulated in various different sectors, the AHTEG shall provide advice or develop elements of technical guidance on management measures on invasive alien species to be implemented by broad sectors to facilitate achieving Aichi Biodiversity Target 9 and beyond:

(a) Methods for cost-benefit and cost-effectiveness analysis which best apply to the management of invasive alien species;

(b) Methods, tools and measures for identification and minimization of additional risks associated with cross-border e-commerce in live organisms and the impacts thereof;

(c) Methods, tools and strategies for the management of invasive alien species as it relates to prevention of potential risks arising from climate change and associated natural disasters and land use changes;

(d) Risk analysis on the potential consequences of the introduction of invasive alien species on social, economic and cultural values;

(e) Use of existing databases on invasive alien species and their impacts, to support risk communication.

4. Accordingly, the Executive Secretary convened the online discussion forum on invasive alien species (Online Forum) with notification 2019-040[1] and a total of ninety eight experts[2] have registered for the forum at https://www.cbd.int/invasive/forum2/. The Online Forum has been formally open from 1 May to 30 September 2019. This document summarizes the information relevant to the tools and methods and other information to support the discussion of the AHTEG, and information on achieving Aichi Biodiversity Target 9 suggested by the participants of the Online Forum, as well as the information from the relevant international organizations (members of the Inter-agency Liaison Group on Invasive Alien Species) during the inter-sessional period since the fourteenth meeting of the Conference of the Parties.

5. By the end of September 2019, the Online Forum website received a total of 258 contributions from the registered participants, providing commentary and examples of the use of various tools. The discussion was structured into a number of threads asking for views and evidence on different aspects of the topic.

6. This document was prepared in close collaboration with the moderators[3] of the Online Forum and experts of the Inter-agency Liaison Group on Invasive Alien Species to cover the information on the tools relevant to invasive alien species management. The information covers not only the tools recognized by Parties to the Convention on Biological Diversity but also applicable measures possibly taken by broader sectors.

7. Section II summarizes the information on existing tools and the views of participants to the online forum related to the requested tools development. Finally, section III provides summary of the suggestions to manage invasive alien species and to provide advice or develop elements of technical guidance on management measures on invasive alien species to be implemented by broad sectors to facilitate achieving Aichi Biodiversity Target 9 and beyond, which will be further considered by the AHTEG.

II. SUMMARY OF THE TOOLS IDENTIFIED AND ADDITIONAL INFORMATION TO APPLY THE TOOLS FOR THE MANAGEMENT OF INVASIVE ALIEN SPECIES

A. Clarification of terminology surrounding alien species

8. For the purpose of synthesising report of the Online Forum and for the AHTEG to be informed, the present document uses the following terms related to invasive alien species, based on the exchanges through the Online Forum and in consultation with the moderators:

(a) **Invasive alien species:** In accordance with Article 8(h) of the CBD,[4] alien species which threaten ecosystems, habitats or species are called invasive alien species. Taking into account the International Plant Protection Convention (IPPC), article II, any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products which do not naturally exist in the area for

[1] Notification 2019-40 https://www.cbd.int/doc/notifications/2019/ntf-2019-040-ias-en.docx

[2] Australia, Bhutan, Brazil, Canada, Central African Republic, China, Cuba, Cyprus, Czechia, Ecuador, Egypt, Ethiopia, European Union, France, Ghana, India, Indonesia, Iran, Israel, Jamaica, Jordan, North Macedonia, Malaysia, Mexico, Nepal (incl. IPLC), Netherlands (overseas territory), New Zealand, Nigeria, Norway, Pakistan, Portugal, Republic of Congo, Slovakia, South Africa, South Sudan, Spain, Saint Lucia, Suriname, Sweden, Tunisia, Turkmenistan, United Kingdom of Great Britain and Northern Ireland, Viet Nam, Zimbabwe, United States of America, Euro Group for Animals, Food and Agriculture Organization of the United Nations, International Maritime Organization, International Plant Protection Convention, International Union for Conservation of Nature (IUCN), IUCN-Invasive Species Specialist Group and World Customs Organization.

[3] Peter Robertson (Newcastle University, UK), Shyama Pagad (IUCN-SSC-Invasive Species Specialist Group, New Zealand), Andy Sheppard (Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia) and Christine Villegas (Canadian Food Inspection Agency (CFIA), Canada).

[4] https://www.cbd.int/convention/articles/default.shtml?a=cbd-08

management are deemed to be invasive alien species, including weeds.[5] Further referring to the World Organisation for Animal Health (OIE) guidelines for assessing risk of non-native animals becoming invasive[6], an animal that has been introduced and subsequently became established and spread outside its native distribution area and caused harm to the environment, animal or human health, or the economy is called invasive alien species. Also, referring to the glossaries of Terrestrial Animal Health Code and Aquatic Animal Health Code under OIE, a biological agent in, or a condition of, an animal or animal product with the potential to cause adverse health effect is a hazard, and the associated risk needs to be considered in the context of invasive alien species. In the terms used in the International Maritime Organization (IMO), harmful aquatic organisms and pathogens and invasive aquatic species are deemed to be invasive alien species and are moved with the ships' ballast water and biofouling;

(b) **Alien species:** In accordance with annex to decision VI/23[7] of the Conference of the Parties to the CBD, "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;

(c) **Establishment:** In accordance with annex to decision VI/23[7] of the Conference of the Parties to the CBD, "establishment" refers to the process of an alien species in a new habitat successfully producing viable offspring with the likelihood of continued survival;

(d) **Risk analysis:** In accordance with annex to decision VI/23[7] of the Conference of the Parties to the CBD, "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) to the identification of measures that can be implemented to reduce or manage these risks (i.e., risk management), taking into account socioeconomic and cultural considerations. Further, taking into account the international standards on phytosanitary measures[8], the OIE Animal Health Codes[9] and the publication of Food and Agriculture Organization of the United Nations (FAO) on aquaculture[10], the process of risk analysis is composed of : (i) **hazard identification** to identify an alien organism in the area of assessment; (ii) **risk assessment** on the alien organism threatening biodiversity in the area whether the risk is acceptable or risk reduction measures need to be applied ; (iii) **risk management** to identify the risk reduction measures and the actions to take ; and (iv) **risk communication** as an integral part of the risk analysis process for exchanging information and opinions between risk evaluators, risk managers and other interested parties, including the peoples and community in the area, considering the consequence on social, economic and cultural values in the area;

(e) **Invasive alien species management:** Application of measures to prevent the introduction of, control or eradicate invasive alien species.

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[5] https://www.ippc.int/static/media/files/publication/en/2019/02/1329129099_ippc_2011-12-01_reformatted.pdf
[6] https://www.oie.int/doc/ged/D13931.PDF
[7] https://www.cbd.int/decision/cop/default.shtml?id=7197 * One representative entered a formal objection during the process leading to the adoption of this decision and underlined that he did not believe that the Conference of the Parties could legitimately adopt a motion or a text with a formal objection in place. A few representatives expressed reservations regarding the procedure leading to the adoption of this decision (see UNEP/CBD/COP/6/20, paras. 294-324).
[8] ISPM2 and ISPM 11 https://www.ippc.int/en/core-activities/standards-setting/ispms/
[9] Aquatic Animal Health Code and Terrestrial Animal Health Code, https://www.oie.int/en/standard-setting/aquatic-code/access-online/ and https://www.oie.int/en/standard-setting/terrestrial-code/access-online/
[10] FAO Fisheries and Aquaculture Technical Paper. No. 519, http://www.fao.org/3/a-i0490e.pdf

B. Methods for cost-benefit and cost-effectiveness analysis which best apply to the management of invasive alien species

B1 Remit of the discussion – Decision-making in the marine environment

9. Contributions were received from a number of participants highlighting the problems faced when managing species in the marine environment. In particular, the postings emphasized the need to focus on prevention, to ensure discussion adequately considered both terrestrial and marine environments and the need for methods to support prevention as a management approach. This was largely supported by the Online Forum.

B2 What do we mean by analysis of costs and benefits?

10. Contributors highlighted a range of different methods to analyse the costs and benefits associated with invasive alien species, or which are used to support decision-making and include the consideration of costs and benefits. In the context of the discussion, these included:

(a) Cost-benefit analysis – using purely monetary values to assess both the costs and benefits of a species or management action;

(b) Cost-effectiveness analysis – contrasting the costs of implementing a programme with the benefits measured in non-economic terms, for example the number of threatened species saved;

(c) Multi-criteria methods – assessing a wide range of different criteria, often measured in different currencies, to prioritize among a variety of different available options. For example, the methods may include the public acceptability, humaneness and wider environmental impacts of management proposals alongside economic costs;

(d) Risk assessment – a formal process, typically based on a combination of available evidence and expert opinion, which assesses the probabilities that a species will enter, establish, spread and cause impacts in an area (see also paragraph 6 of this document);

(e) Risk management – a process of assessing the feasibility and effectiveness of management. In some circumstances this may also be called Impact Management (see also para. 6 of this document);

(f) Risk Analysis – a term referring to the combined use of risk identification, risk assessment, risk management and associated risk communication (see also paragraph 8(d) of this document).

B3 What are the costs and benefits associated with invasive alien species and their management?

10. A table, presented below, describing the different costs and benefits associated with alien species (introduced and invasive) and their management was offered, describing the main currencies in which each was typically measured.

Cost or benefit	Currency of measurement
Cost of species presence	
• Impact of species on human well-being	Social
• Impact of species on wider biodiversity	Biodiversity
• Impact of species on the environment	Environmental
• Impact of species on ecosystem services	Environmental
• Impact of species on economic activity	Economic
Benefit of species presence	
• Economic value of use of new species	Economic

• Addition of new species to local biodiversity	Biodiversity
• Positive effects of new species on other species (including biological control)	Environmental
• Beneficial effect of new species on human well-being	Social
• Beneficial effect of new species on the environment	Environmental
• Improved global conservation status of the introduced species	Biodiversity
Cost of management	
• Restriction in trade	Economic
• Costs of regulation	Economic
• Costs of interception/inspection	Economic
• Welfare impact of management (vertebrates)	Animal welfare
• Costs of surveillance	Economic
• Costs of removal	Economic
• Costs of maintaining contingency capability	Economic
• Social acceptability of management (n.b. The reaction of the public to management)	Social
• Wider environmental impacts of management	Environmental
Benefit of management	
• Reduced risk of future invasion and associated costs	Multiple
• Reduced current impacts	Multiple
• Reduced future impacts	Multiple

11. The Online Forum highlighted a number of points related to these costs and benefits, listed below:

(a) The lack of available information on which to base an assessment of economic costs in many regions;

(b) Most analyses and decisions only consider a small proportion of the costs and benefits described in this list;

(c) The importance of including non-economic measures, such as biodiversity and public acceptability in decision-making;

(d) Difficulties in defining costs and benefits for species occurring both in the wild and in domestic production, highlighting the problems associated with aquaculture;

(e) The need to include environmental as well as economic impacts in decision-making;

(f) The need to consider prevention of spread as well as the management of species, once they have established;

(g) That similar categories may be applied to pathways as well as species, of relevance to pre-border control and prevention;

(h) Although required for completeness, contributors highlighted that a number of the 'benefits of species presence' needed to be considered in a wider context, introduction of new species into an area may increase local species number, but this will be balanced by any detrimental effects on native species. In the longer term, such introduction will also increase the wider homogeneity of ecological communities and break down the geographic barriers that help drive biodiversity;

(i) Similarly, the viability of introducing species into new areas as a conservation tool is questionable, given the uncertainties in predicting the consequences of new introductions, and the associated costs if the introduced species become invasive.

B4 What decisions are informed by these analyses?

12. A variety of different types of decision were described in posts with references. The choice of appropriate methods varied between each. These included:

(a) Demonstrating economic impact, often required to illustrate the importance of an issue or the need to manage;

(b) Showing a net economic benefit of management – often required to gain support for a management action;

(c) Optimizing a management approach – determining the most cost-effective way to implement a programme – with examples provided in relation to surveillance or inspection;

(d) Prioritization – choosing from a wide range of options (species, management alternatives) to best direct cost-effective management.

B5 Availability of databases

13. Contributors highlighted the availability of existing databases and initiatives which can inform a number of costs and benefits described below:

(a) Impact of species on wider biodiversity and the environment – existing Environmental Impact Classification for Alien Taxa (EICAT) initiative[11] and the eneric impact scoring system (GISS);[12]

(b) Impact of species on human wellbeing – existing socioeconomic impact classification of alien taxa (SEICAT) initiative;[13]

(c) Species risk assessments/analysis – a range of regional and national programmes and databases were identified[14],[15],[16], [17] (e.g., Risk Assessments in Belgium, EU, UK, or Australia);

(d) Cost of eradication. A range of studies and databases describe the costs of successful eradications worldwide[18],[19],[20],[21], [22],[23],[24],[25],[26];

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[11] Hawkins, C.L., Bacher, S., Essl, F., Hulme, P.E., Jeschke, J.M., Kühn, I., Kumschick, S., Nentwig, W., Pergl, J., Pyšek, P. and Rabitsch, W., 2015. Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Diversity and Distributions, 21(11), pp.1360-1363.

[12] Nentwig, W., Bacher, S., Pyšek, P., Vilà, M. and Kumschick, S., 2016. The generic impact scoring system (GISS): a standardized tool to quantify the impacts of alien species. Environmental Monitoring and Assessment, 188(5), p.315.

[13] Bacher, S., Blackburn, T. M., Essl, F., Genovesi, P., Heikkilä, J., Jeschke, J. M., Jones, G., Keller, R., Kenis, M., Kueffer, C., Martinou, A.F., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Roy, H.E., Saul, W-C.,Scalera, R., Vilà, M., Wilson, J.R.U., Kumschick, S. (2017). Socio-economic impact classification of alien taxa (SEICAT). Methods in Ecology and Evolution, 1–10.

[14] Risk Assessments Belgium http://ias.biodiversity.be/species/risk

[15] Risk Assessments EU http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

[16] Risk Assessments UK http://www.nonnativespecies.org/home/index.cfm

[17] Arthur,T. Summerson, R.and Mazur, K. (2015) A Comparison of the Costs and Effectiveness of Prevention, Eradication, Containment and Asset Protection of Invasive Marine Species Incursions http://www.agriculture.gov.au/SiteCollectionDocuments/pests-diseases-weeds/marine-pests/comparison-costs-effectiveness-prevention.pdf

(e) Information on measures and related costs in relation to species considered for inclusion on the Union list".[27]

14. In relation to these databases, suggestions were made for new datasets to be established or existing ones improved.

(a) Risk Assessment – There is scope to collate these and make them more readily available, but the need for standardized metadata and quality control was highlighted;[28]

(b) Impacts of Species – A suggestion to extend the field "IsInvasive" in the Global Register of Introduced and Invasive Species (GRIIS) checklists.[29] Here, the difference between current and potential impact becomes important. Currently, the process is to provide evidence of impact to flag it as invasive, which means it is already too late to act. Perhaps it is more proactive to include potential impact in these checklists;

(c) Wider data on the costs of management – A need for more standardized information on the practical costs of management, including prevention, eradication and ongoing management.

B6 Examples of the use of cost and benefit analyses to support invasive alien species management.

15. Recent papers[30],[31] described the use of cost-benefit, cost-effectiveness and cost-utility analyses in relation to the economics of invasive alien species management. These include recent developments to improve the monetization of invasive alien species impacts.

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[18] Brockerhoff, E.G., Liebhold, A.M., Richardson, B. and Suckling, D.M., (2010). Eradication of invasive forest insects: concepts, methods, costs and benefits. New Zealand Journal of Forestry Science 40 suppl. S117-S135

[19] Gardener, M. R., Atkinson, R., & Rentería, J. L. (2010). Eradications and people: lessons from the plant eradication program in Galapagos. Restoration Ecology, 18(1), 20-29.

[20] Holmes, N.D., Campbell, K.J., Keitt, B.S., Griffiths, R., Beek, J., Donlan, C.J. and Broome, K.G., 2015. Reporting costs for invasive vertebrate eradications. Biological Invasions, 17(10), pp.2913-2925.

[21] Holmes, N.D., Campbell, K.J., Keitt, B., Griffiths, R., Beek, J., Donlan, C.J. and Broome, K., 2016. Correction: reporting costs for invasive vertebrate eradications. Biological Invasions, 18(10), pp.2801-2807.

[22] Howald, G., Donlan, C., Galván, J.P., Russell, J.C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M. & Saunders, A. (2007). 'Invasive rodent eradication on islands'. Conservation Biology, 21(5), pp.1258-1268.

[23] Martins, T.L.F., Brooke, M.D.L., Hilton, G.M., Farnsworth, S., Gould, J. & Pain, D.J. (2006). Costing eradications of alien mammals from islands. Animal Conservation, 9(4), pp.439-444.

[24] Rejmánek, M. & Pitcairn, M.J. (2002). 'When is eradication of exotic pest plants a realistic goal.' Turning the tide: the eradication of invasive species, pp.249-253.

[25] Robertson, P.A., Adriaens, T., Lambin, X., Mill, A., Roy, S., Shuttleworth, C.M. & Sutton-Croft, M., 2017. The large-scale removal of mammalian invasive alien species in Northern Europe. Pest Management Science, 73(2), pp.273-279.

[26] Gerda website. http://b3.net.nz/gerda/index.php.

[27]CIRCABC website. https://circabc.europa.eu/w/browse/ead324a2-f37a-461d-b6bf-b3870c7308ce.

[28] Roy, H.E., Rabitsch, W., Scalera, R., Stewart, A., Gallardo, B., Genovesi, P., Essl, F., Adriaens, T., Bacher, S., Booy, O. and Branquart, E., 2018. Developing a framework of minimum standards for the risk assessment of alien species. Journal of applied ecology, 55(2), pp.526-538.

[29] Pagad, S., Genovesi, P., Carnevali, L., Schigel, D. and McGeoch, M.A., 2018. Introducing the global register of introduced and invasive species. Nature Scientific data, 5, p.170202.

[30] Eiswerth, M., Lawley, C. and Taylor, M.H., 2018. Economics of Invasive Species. In Oxford Research Encyclopedia of Environmental Science.

[31] Epanchin-Niell, R.S., 2017. Economics of invasive species policy and management. Biological Invasions, 19(11), pp.3333-3354.

16. Examples were provided of the use of cost-benefit analyses to support decision-making from a number of regions including the Caribbean[32], Africa[33],[34], Europe[35] and Australia.[36]

17. Examples of cost-effectiveness analyses used to assess or optimize the effectiveness of management approaches were also highlighted[37],[38],[39],[40],[41],[42]. As well as providing links to existing databases, papers describing the methods and standards for risk assessment were provided. Examples of the use of multi-criteria methods to assess risk management were provided.[43],[44] Studies were also provided that assessed the social consequences of management[45]. Studies also described the costs of species presence [46],[47], [48],[49]. Other examples and studies related to the paragraphs 15-16 above can be found elsewhere.[50]

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[32] Daigneault, A., Brown, P. and Ramnanan, N., 2014. Economic impact of IAS in the Caribbean: case studies. Economic impact of IAS in the Caribbean: case studies. http://www.ciasnet.org/wp-content/uploads/2015/04/Economic_Impact_of_IAS_in_the_Caribbean_2014.pdf

[33] Wise, R.M., Van Wilgen, B.W., Hill, M.P., Schulthess, F., Tweddle, D., Chabi-Olay, A. and Zimmermann, H.G., 2007. The economic impact and appropriate management of selected invasive alien species on the African continent. Final Report. Prepared For: Global Invasive Species Programme.

[34] Van Wilgen, B.W., De Wit, M.P., Anderson, H.J., Le Maitre, D.C., Kotze, I.M., Ndala, S., Brown, B. and Rapholo, M.B., 2004. Costs and benefits of biological control of invasive alien plants: case studies from South Africa: working for water. South African Journal of Science, 100(1-2), pp.113-122.

[35] Reyns, N., Casaer, J., De Smet, L., Devos, K., Huysentruyt, F., Robertson, P.A., Verbeke, T. and Adriaens, T., 2018. Cost-benefit analysis for invasive species control: the case of greater Canada goose *Branta canadensis* in Flanders (northern Belgium). PeerJ, 6, p.e4283.

[36] Nordblom, T.L., Smyth, M.J., Swirepik, A., Sheppard, A.W. and Briese, D.T., 2001. Benefit-cost analysis for biological control of *Echium* weed species (Paterson's curse/Salvation Jane) (No. 412-2016-25884).

[37] Blignaut, J.N., Marais, C. and Turpie, J.K., 2007. Determining a charge for the clearing of invasive alien plant species (IAPs) to augment water supply in South Africa. Water Sa, 33(1).

[38] Keller, R.P., Frang, K. and Lodge, D.M., 2008. Preventing the spread of invasive species: economic benefits of intervention guided by ecological predictions. Conservation Biology, 22(1), pp.80-88.

[39] Mérel, P.R. and Carter, C.A., 2008. A second look at managing import risk from invasive species. Journal of Environmental Economics and Management, 56(3), pp.286-290.

[40] Epanchin-Niell, R.S., Brockerhoff, E.G., Kean, J.M. and Turner, J.A., 2014. Designing cost-efficient surveillance for early detection and control of multiple biological invaders. Ecological Applications, 24(6), pp.1258-1274.

[41] Kraaij, T., Baard, J.A., Rikhotso, D.R., Cole, N.S. and Van Wilgen, B.W., 2017. Assessing the effectiveness of invasive alien plant management in a large fynbos protected area. Bothalia-African Biodiversity & Conservation, 47(2), pp.1-11.

[42] Springborn M, Lindsay AR, Epanchin-Niell RS (2016) Harnessing enforcement leverage at the border to minimize biological risk from international live species trade. J Econ Behav Org 132(B):98–112

[43] Booy, O., Mill, A.C., Roy, H.E., Hiley, A., Moore, N., Robertson, P., Baker, S., Brazier, M., Bue, M., Bullock, R. and Campbell, S., 2017. Risk management to prioritise the eradication of new and emerging invasive non-native species. Biological Invasions, 19(8), pp.2401-2417.

[44] Zengeya, T., Ivey, P., Woodford, D.J., Weyl, O., Novoa, A., Shackleton, R., Richardson, D. and Van Wilgen, B., 2017. Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. Bothalia-African Biodiversity & Conservation, 47(2), pp.1-11.

[45] Creed, J. C., Junqueira, A. D. O. R., Fleury, B. G., Mantelatto, M. C., & Oigman-Pszczol, S. S. (2017). The Sun-Coral Project: the first social-environmental initiative to manage the biological invasion of *Tubastraea* spp. in Brazil. Manag. Biol. Invasions, 8, 181-195.

[46] Bradshaw, CJA, Leroy, B, Bellard, C, Roiz, D, Albert, C, Fournier, A, Barbet-Massin, M, Salles , J-M, Simard, F, Courchamp, F. (2016). Massive yet grossly underestimated global costs of invasive insects. Nat. Commun. 7, 12986 doi: 10.1038/ncomms12986

[47] Hoffmann, B.D. and Broadhurst, L.M., 2016. The economic cost of managing invasive species in Australia. NeoBiota, 31, p.1.

B7 Descriptions of national approaches to support decisions-making

18. A number of countries provided links or descriptions of their national processes to assess and prioritize the management of alien species:

(a) Norway described how they conducted cost-effectiveness analysis of mitigation measures as they often lack benefit estimates. Government guidelines for cost-benefit analysis (and cost-effectiveness analysis) from the Norwegian Ministry of Finance as well as the ecosystem service approach and environmental valuation methods and benefit transfer techniques are increasingly being used as an additional decision tool in environmental management;

(b) In Mexico, a preliminary exercise was conducted for the years 2007 to 2012, to find out what would be the cost for the private sector that imports invasive alien species, if the imports of certain exotic species were prohibited through regulation. Also, the benefits of regulating imports of IAS were quantified; the avoided costs were quantified for damages and impacts and for control and eradication. To do this, the costs of control, eradication and economic damages were taken as reference, in which a number of countries have incurred as a consequence of the introduction of IAS of algae, plants, aquatic invertebrates, terrestrial invertebrates, fish and vertebrates;

(c) In relation to South Africa, a paper was provided which used a multi-criteria scoring approach to review the benefits and negative impacts of species currently listed in their Alien and Invasive Species Regulations;

(d) For the UK, links were provided to their risk analysis framework, which includes risk assessment and risk management methods, to assess the risks and priorities for management of different species. A paper describing the use of a multi-criteria method applied to species risk management and prioritization was provided;[37]

(e) In Australia, they have been undertaking successful environmental invasive alien species management for more than 70 years and no longer explicitly apply a classic cost-benefit approach because of the difficulty of valuing the $ benefits to environmental assets for most activities. They have therefore moved to "cost-effectiveness analysis" which looks at collective assessment of the relative effectiveness of a range of different actions at achieving the desired environmental outcome. They have found this much more effective in community co-development and costing of management plans around specific “Specific Measurable Achievable Relevant Time-bound” (SMART) management goals;[51]

(f) In Ecuador, a risk assessment system is being developed for exotic species and a tool for cost-benefit analysis is important to help decision-making regarding the management of these species;

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[48] Economic Impacts of Invasive Species: Direct Costs Estimates and Economic Impacts for Washington State, January 2017
https://invasivespecies.wa.gov/council_projects/economic_impact/Invasive%20Species%20Economic%20Impacts%20Report%20Jan2017.pdf

[49] Economic Impact From Selected Noxious Weeds in Oregon
https://www.oregon.gov/oda/shared/documents/publications/weeds/ornoxiousweedeconomicimpact.pdf

[50] Leung, B., Lodge, D.M., Finnoff, D., Shogren, J.F., Lewis, M.A. and Lamberti, G., 2002. An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proceedings of the Royal Society of London B: Biological Sciences, 269(1508), pp.2407-2413.

[51] Carwardine, J., O’Connor, T., Legge, S., Mackey, B., Possingham, H.P. and Martin, T.G., 2012. Prioritizing threat management for biodiversity conservation. Conservation Letters, 5(3), pp.196-204.

(g) In Belgium, impact assessments have been performed for a number of species, and more detailed full risk assessment for a limited set of species (http://ias.biodiversity.be/species/risk), some of which have been used to justify inclusion of species on the EU List (Risk Assessments Belgium);

(h) The European Union have been undertaking risk assessments to support the Listing of Species of Union Concern (Risk Assessment EU).[52]

C. Tools to address the risks associated with e-commerce

19. Trade through e-commerce uses the same physical distribution modes as traditional trade such as marine vessels, overland mail and air freight. However, e-commerce creates a significant shift in the way trade occurs and allows global access to items that previously would have been difficult to find and purchase (e.g. alien animals and plants for use as pets or ornamental purposes). Understanding the impact of this disruption is an important step towards understanding how best the risk can be minimized and the tools needed. Under this section, e-commerce crossing the borders (national boundaries and biogeographic boundaries) and associated risk of biological invasions were discussed.

20. The Online Forum considered the following items to the group:

(a) How do we define e-commerce?

(b) Why is e-commerce a challenge for managing invasive alien species?

(c) What are the roles and responsibilities of the various stakeholders, partners, risk-makers and government organizations involved?

(d) Examples of how jurisdictions have resolved specific e-commerce issues (both positive and negative outcomes) and what tools or measures are already in place or under development;

(e) Where are the gaps in legislation, outreach and awareness, data collection and analysis, monitoring and enforcement considering the most effective control points along the entire supply chain continuum?

21. The international organizations that set standards or guidance for cross-border trade have determined the term e-commerce (or E-commerce) as follows:

(a) CBD – The trade of commodities conducted electronically on the Internet. E-commerce in live specimens obtained from wildlife, as well as plants for planting, seeds and products that contain seeds, and potentially associated living organisms;[53]

(b) IPPC – Sales of plants and plant products ordered through the internet;[54]

(c) WCO – Online ordering, sale, communication and payment, in particular business to consumer and consumer to consumer transactions but can also be applicable to business to business transactions[55].

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[52] https://ec.europa.eu/environment/nature/invasivealien/index_en.htm

[53] UNEP/CBD/SBSTTA/20/7 on invasive alien species https://www.cbd.int/doc/meetings/sbstta/sbstta-20/official/sbstta-20-07-en.pdf

[54] Recommendation on: Internet trade (e-commerce) in plants and other regulated articles R-05 2017 adopted 2014 https://www.ippc.int/static/media/files/publication/en/2018/11/R_05_En_2017-08-24_Combined_2018_MinorEditorial.pdf

C1 Challenges

22. During the Online Forum, the IPPC highlighted that sales of plants and plant products ordered through the internet (e-commerce) and courier mail services have increased significantly in the years since the IPPC and most of the International Standards for Phytosanitary Measures (ISPMs) were adopted. E-commerce is fueling an increasing volume of traded commodities. In many cases online traders of plants and plant products do not take into account a customer's location before agreeing to a sale and shipping their purchases to them. This lack of knowledge of a customer's location can lead to consignments of regulated articles being imported into a country without any effort to meet the phytosanitary requirements of the customer's country.

23. It is expected that e-commerce and the shipment of products via courier services will grow significantly. This will be associated with an upsurge in regulated articles traded and shipped internationally by mail services. Phytosanitary services around the world will need efficient tools and procedures to screen courier mail and small packages. In addition, international harmonization of measures and procedures for e-commerce and courier mail operators may be the most efficient way to address this problem.

24. Globally, e-commerce volume and value are expected to increase annually. In 2019, retail e-commerce sales worldwide amounted to 3.53 trillion US dollars and e-retail revenues are projected to grow to 6.54 trillion US dollars in 2022. From a regulatory perspective, this high volume and rapid expansion of e-commerce trade makes it very difficult to monitor and enforce without hindering commerce and the interest for expedited releases.

16. E-commerce is a relatively new phenomenon for developing countries, it may not yet be recognized as an enabling factor in pest introduction and spread or there may not be resources to assess the risk and implement adequate mitigation measures. In other countries, such as South Africa, e-commerce is a potential concern, but it is difficult to quantify its contribution to the trade and movement of invasive alien species in comparison to other existing factors such as lack of awareness among users of e-commerce on existing import requirements, and incorrect identification of articles or mis-declaration.

17. E-commerce has facilitated the finding and purchasing of new plants[56]and living organisms which consumers did not have prior access to and which are typically delivered by mail[57]. In many countries, e-commerce packages go unchecked and proper process such as having a phytosanitary certificate is not followed or enforced. Many of the issues with e-commerce is a result of the switch from businesses importing in large quantities to individuals (with little or no knowledge of import requirements) importing small quantities delivered directly to their door by courier.

18. Many of the challenges relate to the fact that e-commerce is a new way of shopping – it is new to regulators, businesses, consumers and the general public. Many of the businesses and consumers involved in e-commerce are also new to the world of import/export and are unknown to the regulators. Certainly, articles that are prohibited entry to a country are unlikely to be found in traditional retail stores in that country. In addition, with e-commerce sales, the purchaser may not know the origin of the product or the location of the seller and the seller may not know the location of the purchaser.

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[55] Cross-Border E-Commerce Framework of Standards http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/facilitation/activities-and-programmes/ecommerce/wco-framework-of-standards-on-crossborder-ecommerce_en.pdf?la=en

[56] Champion, P.D. and J. S. Clayton. 2000. Border control for potential aquatic weeds. Science for Conservation 141. Department of Conservation, Wellington, NZ

[57] Giltrap, N., E. Eyre and P. Reed. 2009. Internet sales of plants for planting – an increasing trend and threat. OEPP/EPPO Bulletin 39:168-170

19. The volume of parcels moving through the mail and courier pathway is enormous and increasing. Most of these goods are being ordered through the internet and there is considerable pressure for rapid delivery services. Huge volumes of regulated articles move internationally through traditional trade and distribution mechanisms too.

20. The massive influx of small, individual parcels creates challenges to differentiate high risk from low risk and to identify and target potential biosecurity threats. Adequate tracking and monitoring systems, including data on internet sales, are problematic to obtain, manage and share, especially for regulatory purposes. Under these circumstances, the risk of biological invasions as a result of e-commerce is raised as a concern in many parts of the world.

21. Although many countries provide lists of species which are regulated on their import, possession or trade, the internet provides a platform to trade such a vast range of species (including potentially invasive species) without appropriate risk analysis, that some countries such as Belgium have opted for a positive list whereby only the listed species are permitted based on scientific risk assessment.

C2 Roles and Responsibilities

22. A review of several articles suggests that there is a general lack of awareness by e-commerce vendors and buyers on what they are actually selling, buying, or trading, on existing plant and animal health regulations and their role in ensuring import or export requirements are met or in reporting contaminating pests to national authorities[52]. Some national authorities of importing countries are often unaware of items traded via the internet because they will eventually be imported and delivered by mail service or courier directly to the customers, bypassing the usual processes that verify compliance with the country's import requirements set by the national authorities on sanitary and phytosanitary measures[58].[59] This is further compounded when items are misidentified, incorrectly declared or traded on free sharing sites by anonymous users of e-commerce.[60]

C2 Specific country examples

Australia

23. Australia has traditionally managed e-commerce trade by x-raying mail items. Ten years ago, x-raying was applied to 100% of incoming mail. However, this is no longer feasible with massive increases in e-commerce. The number of parcels is increasing at 10% a year (currently 1.6 billion) with international inbound parcels growing at more than 40% a year. Australia is developing an e-nose technology as a long-term replacement for sniffer dogs but it is still in prototype. Recommendations of a recent review have been the following:

(a) Biosecurity public awareness campaign regarding limited financial benefits of selling prohibited commodities, relative to the significant financial penalties;

(b) To continue engagement with e-commerce industry (agreements already in place with eBay and Amazon) to better manage the biosecurity risks of trading in invasive species;

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[58] Reichard, S. H. and P. White. 2001. Horticulture as a pathway of invasive plant introductions in the US. BioScience, volume 51, issue 2, pages 103-113. World Customs Organisation. 2018. Cross-border e-commerce framework of standards.

[59] International Plant Protection Convention. 2012. Internet trade (e-commerce) in plants potential phytosanitary risk.

[60] Keller, R. P. and D. M. Lodge. 2007. Species invasions from commerce in live aquatic organisms. BioScience 57: 428-436

Thum, R., A. Mercer and D. Weisel. 2012. Loopholes in the regulation of invasive species: genetic identifications identify mislabelling of prohibited aquarium plants. Biological Invasions 12:929-937

(c) To require e-commerce industry to ensure clients know their legal obligations with respect to buying, selling and transporting commodities that represent biosecurity risks;

(d) Legislative reforms to ensure effective regulation of traders, consumers and e-commerce platforms with requirements for the provision of information by the e-commerce industry;

(e) To review effectiveness of a range of software applications for monitoring social media regarding high risk e-commerce activity;

(f) To legislate significant penalties for e-commerce platforms that facilitate the advertisement of illegal matter on their sites;

(g) To develop an Australian standard for the management of biosecurity risks in the e-commerce and retail industries involved in trading commodities with biosecurity risks and ensure regulators have appropriate powers to access information from e-commerce organizations;

(h) To train specialty investigators to work covertly and collect evidence from the internet and other digital sources so it is admissible in court;

(i) To invest in research, development and engineering specialty tools to equip regulators and investigators for regulating the e-commerce market;

(j) To undertake a National review of the sale of live organisms via e-commerce.

Belgium

24. Belgium has some very useful tools available to inform species prioritization for prevention and control. In practice, involving sufficient experts and mobilizing resources to actually use such protocols are being applied in a limited manner. Initiatives are underway to better make use of available distribution data through software pipelines fostering more integrated, data-driven procedures for risk evaluation. The European Court of Justice has provided its support for the positive list approach.

Brazil

25. Brazil has considered e-commerce as an important potential introduction of invasive species, especially for pets, aquarium and ornamental plants and an issue for both cross-border and domestic trade. A set of actions is being developed to address the IAS risks associated with e-commerce according to the scope of the National Strategy on IAS and to identify major gaps in the legislative framework. For animal species, Brazil uses positive lists to import, keep and trade. Brazilian experts are developing risk analyses to identify priority high-risk invasive species that will help to monitor e-commerce platforms and social media and are working on a public awareness campaign about the risks for the environment of buying and keeping wild species as pets. In Brazil, main e-commerce platforms monitor live species trade, which contributes to the reduction of illegal activities. These platforms have been collaborating with investigations of possible offenders. There are also negotiations of Agreements between the Environmental Authority (IBAMA) and the e-commerce platforms. Special investigative operations carried out in Brazil have identified social media as the main platforms for live animal illegal trade. Facebook contributed 97% of the illegal activities. This fact is being explained by the difficulty of identifying and prosecuting offenders. IBAMA has been working in partnership with the US Embassy to get information and prosecute offenders because Facebook servers are located in USA.

Canada

26. Canada started looking at the risks associated with e-commerce using a small group of high risk plant pests and different online search engines to find websites that may be offering to sell or trade those species. The findings were documented and used to develop the rationale for a more in-depth investigation of this issue. One of the principle focuses is on outreach and communication. Buyers, sellers, and traders on e-commerce platforms may not necessarily consider themselves importers and exporters and may be unaware that rules are in place and need to be complied with whether or not imports or purchases are made on-line. Currently under development is software to automate the search and

systematically collect the needed data from websites. This will allow for better targeting for communication materials, and for more informed regulatory actions or changes to better prevent and respond to biosecurity threats.

China

27. In China, The Law of E-commerce has been implemented in 2019. General Administration of Customs, China also has established several relevant regulations.[61] China is using the image identification system using the technology of Artificial Intelligence which is effective to check the consignments sold via e-commerce. In addition, China operates sampling and inspection based on the Custom risk management procedure.

New Zealand

28. New Zealand is looking at ways to leverage e-commerce to achieve operational efficiencies and faster clearance times while managing biosecurity risks, including for IAS. The work done to date highlights that e-commerce risk management strategies will require non-regulatory as well as regulatory solutions. Examples might include education of consumers on IAS risks or cooperation with online platforms to reduce the volume of risk goods, such as seeds before they enter the supply chain. This work will require dialogue and information sharing based on partnership between government, business and consumers. This concept is embedded in New Zealand's Biosecurity 2025 goal of building a 'biosecurity team of 4.7 million' (i.e. every New Zealander). The '4.7 million programme will develop a specific behaviour change campaign targeting individuals and small businesses who purchase online from offshore websites. Advances in technology and the way business uses technology presents opportunities to improved biosecurity and risk management outcomes, including for IAS. For example, the availability of data, big data analysis and the use of artificial intelligence could revolutionize our understanding of what goods are traded, where and when. This in turn can be leveraged to remove from or trace high risk items through the supply chain thereby eliminating risk or improving incident response.

C3 Gaps of tools and considerations

29. The Online Forum identified the gaps and considerations on the current measures to address the risks associated with e-commerce, as follows:

(a) What are some of the popular software used in different countries to monitor e-commerce trade? What is their efficacy? Is there any data available on this?

(b) How can we access e-commerce data while also providing appropriate privacy, consumer rights or commercial protections?

(c) What regulatory controls have been successfully put in place to avert potential biosecurity threats due to e-commerce?

(d) Would it be beneficial to develop some industry standards or code of conduct for e-traders?

(e) How can a country start to monitor the e-commerce introduction?

(f) How are border officers informed about potential threats in e-commerce and associated transportation modes? What tools are needed to better identify and target small parcels?

[61] http://www.customs.gov.cn/eportal/ui?pageId=696401&currentPage=1&moduleId=803a199eac704a97a8ea1f0a18cb3a0e

(g) As most current commerce activities use the internet for part or all of their transactions, are there certain types of commerce that are more risky and how can they be prioritized?

(h) The resources required to effectively monitor e-commerce activity in real time may not be feasible using traditional methods. What new technology or approaches need to be developed and can these methods be shared with other countries?

(i) How can countries collaborate to exchange information on non-compliances and coordinate monitoring and enforcement actions?

(j) Risk communication has not received a lot of attention, but the lack of awareness of the risks and regulations is noted as one of the main reasons for non-compliant behaviour. China suggested that countries jointly establish a sharing platform for biosecurity risk publicity and education that allows traders to be informed and communicate relevant information to customers simultaneously.

(k) Not only monitoring e-commerce trade but other social media sites such as Facebook and the deep web should also be considered.

30. The Online Forum revealed information further to be considered by the AHTEG to fill the gaps on considerations related to e-commerce, as follows:

(a) The World Customs Organization (WCO) has developed Cross-border E-Commerce framework for standards[62] in which the use of advance electronic data for effective risk management is cross-cutting and underpins trade facilitation, security and safety, revenue collection and measurement and analysis. Through the exchange of advance electronic data leading to efficient risk management, the efficiency of the supply chain can be improved while ensuring compliance with regulatory requirements. Further to the Cross-border E-Commerce Framework for Standards, the WCO council adopted Technical Specifications – Framework of Standards on Cross-Border E-Commerce[63] in June 2019, which states: To safeguard the E-Commerce supply chain, Customs administrations, in cooperation with other relevant government agencies, should prepare and regularly update a list of prohibited and restricted goods in their respective countries and make it easily available to all relevant stakeholders. Key areas concerning safety and security issues include, but are not limited to:

(i) Product safety;

(ii) Living organisms, invasive alien species, pests, pathogens and products derived from animals, plants and fungi that may carry the risk of biological invasions in importing countries;

(iii) CITES plants and animals;

(iv) Agricultural risks (e.g., Phytosanitary);

(v) Sanitary risks; and

(vi) Hazardous substances (e-waste).

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[62] Cross-border E-Commerce framework for standards http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/facilitation/activities-and-programmes/ecommerce/wco-framework-of-standards-on-crossborder-ecommerce_en.pdf?db=web

[63] Framework of Standards on Cross-Border E-Commerce http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/facilitation/activities-and-programmes/ecommerce/1_technical-specifications_en.pdf?db=web

(b) The International Plant Protection Convention at its 9th and 12th sessions of the Commission on Phytosanitary Measures produced recommendation on e-commerce in plants and other regulated articles[64]. Regarding the consignments sold via e-commerce and exchanged by hobbyists, collectors, researchers, etc over the internet (plants for planting, other articles such as plants for consumption, soils, growing media, and living organisms that are known or have the potential to be plant pests), if the customer's location is not known, it can lead to by-passing the import regulations and therefore, those consignments of regulated articles can enter into the country without the phytosanitary certificates. The phytosanitary certificate may be required by the National Plant Protection Organization (NPPO) of that country. To this end, the National Plant Protection Organizations and Regional Plant Protection Organizations are encouraged:

(i) To develop mechanisms for identifying e-commerce traders based within their countries and regions.

(ii) To establish mechanisms to identify products of concern that may be purchased via e-commerce, with a focus on potential high-risk introduction such as plants for planting, soils and growing media and living organisms, and to explore options ensuring they comply with appropriate phytosanitary regulations based on risk assessment.

(iii) To promote compliance by customers and traders operating through e-commerce with the phytosanitary import requirements of importing countries and provide adequate information on the risks posed by by-passing such requirements.

(iv) To strengthen coordination with postal and express courier services to ensure that relevant information of the phytosanitary risks and phytosanitary measures are conveyed to e-commerce traders.

(v) To investigate the phytosanitary risks posed by all forms of distance selling and if necessary to include these purchasing methods in their risk management activities.

(vi) To raise awareness of the risks of by-passing phytosanitary regulations.

(c) The IPPC further advised to the Online Forum that a coordinated international effort to address the spread of pests and pest host material sold through e-commerce and distributed through rapid mail and courier pathways is needed. Examples of activities to be carried out during 2020-2030 could include:

(i) An international communications effort targeting companies trading through e-commerce channels and consumers to ensure they understand that the importing country may have phytosanitary requirements, why those requirements exist, and how to comply with phytosanitary import requirements;

(ii) Establishment of an inter-agency network (CITES/WCO/IPPC) to create synergy in developing a joint policy and recommendations with regard to e-commerce and courier/postal pathways;

(iii) A joint inter-agency toolkit could also be developed for the regulation and screening of courier/postal pathways.

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[64] Recommendation on Internet trade (e-commerce) in plants and other regulated articles https://www.ippc.int/static/media/files/publication/en/2018/11/R_05_En_2017-08-24_Combined_2018_MinorEditorial.pdf

(d) An insightful horizon scanning for future invasive plants with e-commerce as a "pathway" is published[65], as well as on e-commerce trade in invasive plants;[66]

(e) New Zealand's Biosecurity 2025 goal: e-commerce risk management strategies will require non-regulatory as well as regulatory solutions. Examples might include education of consumers on IAS risks or cooperation with online platforms to reduce the volume of risk goods such as seeds before they enter the supply chain. Work will require dialogue and information sharing based on partnership between government, business and consumers. This concept is embedded in New Zealand's Biosecurity 2025 goal of building a biosecurity team of 4.7 million i.e. every New Zealander.

D. Prevention of potential risks arising from climate change and associated natural disasters and land use changes

31. Prior to the commencement of the Online Forum, an underlying document was prepared for the CBD Secretariat by members of the IUCN Species Survival Commission's Invasive Species Specialist Group and the Climate Change Specialist Group[67] that discussed the impact of climate change, land use change and natural disasters on 1) the transportation and introduction of alien species, 2) on the survival and reproduction of alien species and 3) their dispersal across geographical barriers; and 4) the management of invasive alien species taking into consideration the three drivers and the challenges encountered. This document served as a basis for the topic under discussion.

32. Climate change, land use changes and natural disasters are expected to alter invasions stages from arrival and establishment to spread of alien species by facilitating alien populations or species to overcome barriers to invasions.

33. The discussion began with suggested topics for discussion which included:

(a) What are the responses to climate change interactions (including natural disasters) at various stages of biological invasions including transportation, introduction establishment and spread? Examples include Horizon Scanning exercise;

(b) What are the responses to land-use change interactions at various stages of biological invasions including transportation, introduction, establishment and spread? Examples include Surveillance for invasive alien species in disturbed areas.

D1 Land use change discussion and the bias towards terrestrial biomes

34. The first discussion topic that was raised was the apparent bias towards the terrestrial biomes in all discussions to do with land use change and its impacts. It was confirmed that the aquatic/marine biomes were well within the scope of this discussion. The International Maritime Organisation (IMO) shared with the forum that the ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV) has a Terms of Reference "Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic".

35. It was also observed that the 'biophysical envelope'/'environmental niche' modelling, a set of physical and biological parameters defining a potential and/or realized niche of a species, has been widely used to predict potential species distributional changes resulting from a changing climate. However, often data in the marine realm is limited, although available biological data sources were mentioned[68], [69], [70], [71],

[65] www.invasives.org.za/files/36/2015/882/1.%20cobi12579.pdf
[66] https://www.researchgate.net/publication/280774833
[67] This document will be made available to the forum soon
[68] Marine Geospatial Ecology lab, https://mgel.env.duke.edu/resources

[72],[73]. The modelling of species distribution related to biological invasions faces additional issues. The models assume that the observed distributions are in equilibrium with their environment, when they are patently not, and avoid considerations of biotic interactions. To improve the model, studies suggestions were made: to apply data from both native range and invaded areas and to apply data of invasion absence. Examples illustrating this were shared with the Online Forum – A biophysical model based on multiple parameters predicted that the area adjacent to the Suez Canal was not conducive to the establishment of the Indo-Pacific Lionfish, *Pterois miles*, whereas the Bay of Marseilles (France) was. In fact, the entire Levant coastline is inundated by lionfish, whereas not one has been recorded yet in France.[74],[75]

36. Golani's round herring, *Etrumeus golanii*, known from the upper shelf in the northern Red Sea, has entered the Mediterranean through the Suez Canal and spread to Algeria. The sea surface temperature in the northern Gulf of Aqaba ranges between 21.2-27.8°C whereas it is only 14.5-24.5°C off Algeria. Likewise, the burrowing goby, *Trypauchen vagina*, occurs in the Indo-west Pacific Ocean in shallow estuarine and coastal areas, such as the Persian Gulf where sea surface temperatures range between 20 and 32°C, but it is also abundant in Iskenderun Bay, Turkey, where the temperature is 17.5-28.5°C. Both fish were recorded in the Mediterranean at 200 m depth – far beyond their known native depth range. The wide-ranging invasion of Erythraean Sea species in the Mediterranean, and their recently observed intrusion into the lower continental shelf and upper slope, revealed that thermal niche estimations assuming niche conservatism and based on the species' native environment may underestimate their true 'environmental niche[76]'.

37. A point was raised on the stronger impact of increased CO_2 levels on the extent of cover of alien and invasive species foci rather than elevations in global temperatures especially in arid and semi-arid zones. The contributor cited the example of the spread of alien Mesquite (*Prosopis juliflora*) in Africa's drylands that could partly be explained by increase in CO_2 levels in conjunction with other factors. It was concluded that more attention needed to be paid to the dynamics of alien invasive plants in arid and semi-arid areas. A journal article[77] on this topic was shared with the forum.

D2 Climate change and impacts on Nordic countries

38. A contributing member from the Swedish Environmental Protection Agency reminded the forum of the impacts of a warming climate on the potential spread of species in the Nordic countries, where cold temperatures and months of freezing temperatures combined with a short growing season proved an effective barrier for the spread of many alien plant and insect species. With warmer winters and shorter periods of freezing temperatures, alien and invasive species such as the yellow skunk cabbage (*Lysichiton americanus*), Egyptian goose (*Alopochen aegyptiacus*) and the Red-eared slider (*Trachemys scripta*) were known to survive in south Sweden and potentially be able to spread northwards. An effective monitoring

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[69] Marine Cadastre, https://marinecadastre.gov/data/
[70] Bio-Oracle, http://www.bio-oracle.org/
[71] NorthEast Ocean data, http://www.bio-oracle.org/
[72] Marspec, https://esajournals.online library.wiley.com/doi/abs/10.1890/12-1358.1
[73] European Marine Observation and Data network, http://www.emodnet.eu/what-emodnet
[74] Johnston, M., & Purkis, S. (2014). Are lionfish set for a Mediterranean invasion? Modelling explains why this is unlikely to occur. Marine pollution bulletin, 88(1-2), 138-147.
[75] Kletou, D., Hall-Spencer J.M. & Kleitou P. (2016) A lionfish (*Pterois miles*) invasion has begun in the Mediterranean Sea. Marine Biodiversity Records 9, Article number: 46
[76] Galil, B. S., Danovaro, R., Rothman, S. B., Gevili, R., & Goren, M. (2019). Invasive biota in the deep-sea Mediterranean: an emerging issue in marine conservation and management. Biological invasions, 21(2), 281-288.
[77] Lu, X., Wang, L., & McCabe, M. F. (2016). Elevated CO2 as a driver of global dryland greening. Scientific Reports .

of alien species spread and an eradication system that was quick to react were required taking into account that these species are outside the List of Invasive Alien Species of Union concern.[78]

D3 Risk assessments factoring climate change scenarios, both current and projected

39. Risk assessments as a crucial tool to prevent the introduction of harmful alien and potential invasive species especially 'intentional introductions' was highlighted. Factoring climate change scenarios, both current and projected, is a must when conducting these risk assessments depending on the status of alien/invasive species and their presence over the long term. For species that are already established, it is important to assess the range and extent to which the species may spread over the next few decades based on a changing climate, so the risks of their spread can be managed. In the case of species that have been accidentally introduced, an assessment needs to be made of their survival under existing climatic conditions. In the case of probable establishment their potential spread needs to be assessed under different climate scenarios. For species that are being considered for intentional introduction with an assumption that there is a very low chance of invasive behaviour under current climatic conditions, their behaviour under different climate scenarios needs to be studied before any permission is granted for importation. Examples of such tools were shared in the forum.[79]

D4 Other tools and actions as responses to climate change interactions through the various stages of introduction of alien and invasive species spread

40. Some of the potential responses to climate change interactions through the various stages of introduction of alien and invasive species spread include:

(a) Using Horizon scanning and modelling to prioritize alien species and pathways of introduction that represent a risk under climate change;

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[78] The core of Regulation (EU) 1143/2014 is the list of Invasive Alien Species of Union concern (the Union list). The species included on the Union list are subject to restrictions and measures set out in the Regulation. These include restrictions on keeping, importing, selling, breeding and growing. Member States are required to take action on pathways of unintentional introduction, to take measures for the early detection and rapid eradication of these species, and to manage species that are already widely spread in their territory < https://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm>

[79] (1) Government of Canada. (2008). Integrating Climate Change into Invasive Species Risk Assessment Risk Management Workshop Report. Ottawa, Canada: PRI Project Sustainable Development <http://publications.gc.ca/collections/collection_2008/policyresearch/PH4-47-2008E.pdf>

(2) Example of some early work on modelling from Australia including case studies Kriticos, D.J., Crossman, N.D., Ota, N. & Scott, J.K. (2010) Climate change and invasive plants in South Australia. Report for the South Australian Department of Water, Land and Biodiversity Conservation. CSIRO Climate Adaptation Flagship, Canberra, Australia. 92pp<https://publications.csiro.au/rpr/download?pid=csiro%3AEP092039&dsid=DS3>

(3) The Swedish Species Information Centre, part of the Swedish University of Agricultural Sciences, has conducted risk assessment for thousands of alien species that have been observed in Sweden or in nearby countries. Assessments for about 5000 species were conducted using EICAT (Environmental Impact Classification for Alien Taxa) of the IUCN. GEIAA (Generic Ecological Impact Assessment of Alien Species (Version 3.3) developed by Norway was used to conduct assessments for over 1000 additional species. Climate change scenarios and projects have been included in these assessments. The results are available from this link- please note that the document language is Swedish

https://www.artdatabanken.se/globalassets/ew/subw/artd/2.-var-verksamhet/publikationer/29.-artdatabankens-risklista/rapport_klassifisering_av_frammande_arter2.pdf

(b) Building biosecurity capacity and enacting management action;

(c) Policies restricting the import or use of alien species that have the potential to become invasive in a changing climate;

(d) Incorporating priority alien species under climate change into early detection and eradication measures;

(e) Eradication of species that are established but not currently widespread that may become invasive under climate projections;

(f) Prioritizing habitats and areas that may be susceptible to invasions due to climate change and eradication of alien and potentially invasive species in these areas;

41. The use of Horizon scanning and modelling exercises, risk assessments factoring climate change are recognized as key tools in the management of invasive alien species taking climate change into consideration.

Contributions from participants

42. A contributor from Cameroon, Africa, drew attention to the land-use change in the littoral and mangrove areas of Cameroon and Nigeria driven by poverty and over-exploitation of key woody species such as the mangrove (*Rhizophora racemosa*). Mangrove sites have been invaded by an alien Indo-Pacific mangrove (*Nypa fruticans*) that forms dense mono-typical stands. It was also mentioned that there was limited expertise in this area in Cameroon.

43. A contributor from Egypt drew the forum's attention to invasive alien species in Egypt and the increased effort of the government of Egypt including the development of a national plan in accordance with CBD guidelines, and a monitoring programme to survey the Suez and the Egyptian Mediterranean for alien marine organisms, including pathways of introduction and socioeconomic impacts. Climate change impacts on the spread of alien and invasive species in freshwater systems is being recorded. Examples of jellyfish blooms along the northern coasts of the Egyptian Mediterranean and shifts in fish community compositions because of climate change were cited.

44. A contributor from Australia observed that the impacts of a changing climate is a 'hot' topic of discussion in Australia. Drought in Eastern Australia is considered an extreme weather event. It is noted that less diverse communities dominated by invasive alien species were more vulnerable than drought resistant native communities. However, it was noted that alien and invasive species in these affected communities were likely to recover at a faster pace than native species, raising issues on the management of these species post-drought. A study that conducted a retrospective analysis of this for the Australian Federation drought at the end of the 19th and start of the 20th Century was shared with the forum.[80]

45. The same hypotheses were applied to the post-fire context in Mediterranean-type regions where the heat increases considerably the germination rate of invasive plants such as wattles (and other species).

46. The need for guidelines for the control of invasive alien plants specifically in the aftermath of such events was mentioned.

47. Attention was drawn to the impacts of invasive alien species in changing fire regimes such as the large biomass of African grasses in the Northern savannas leading to the conversion of forested savannas

[80] Godfree, R. C., Knerr, N., Godfree, D., Busby, J., Robertson, B., & Ensinas-Viso, F. (2019). Historical reconstruction unveils the risk of mass mortality and ecosystem collapse during pan-continental megadrought. Proceedings of the National Academy of Sciences of the United States of America.

to alien invasive grass dominated savannas. Another example cited by a contributor from South Africa was the recent fire outbreak in Knysna (garden route), due to the replacement of natural fynbos vegetation with pine plantations in the southern Cape, and the subsequent invasion of surrounding land by invasive pine trees, significantly increasing the severity of the 2017 Knysna wildfires. The biomass from the invasive alien plants, served as fuel for the fires. It is also important that there are other delayed responses that may affect the on setting of invasive species such as the soil seed bank that needs to be addressed.[81]

D5 Climate based species distribution modelling and tools to assist in management

48. Observation of a contributor from Portugal – The application of predictive models in biodiversity science and conservation biology is considered a remarkable success story, with contributions at both the fundamental and the applied arenas. In recent years, the exciting new opportunities offered by satellite Earth observation are fostering a "remote sensing" revolution in ecological research and more particularly in biodiversity research and conservation. There has been substantial application of remote sensing in the study and management of invasions, and there is wide potential for further contributions. However, applications of modelling tools and Earth observation data to anticipate future invasions and their potential impacts, as well as to contribute to their management are still underexplored.

49. Contributors from Australia and New Zealand shared literature and the work done in these countries related to climate based species distribution modelling to show a) how current invasive alien species will increase or decrease in importance under climate change (within and between years) and b) where in the world are the likely impacting sources of future invasive species both under current climate scenarios and under future climate scenarios informing where we should refocus our biosecurity risk pathway work in the future. Examples of climate distribution models were given[82],[83],[84],[85].

Examples of tools that support climate change adaptation

1) AdaptNRM – a national initiative that aims to support National Resource Management (NRM) groups in updating their NRM plans to include climate adaptation planning. The tool provides a framework for planning weed management under a changing climate and includes a technical guide, A Weeds and Climate Change Technical Guide, that is available for download[86]. The module also features supporting materials and species-specific datasets through the CSIRO data access portal, including links to specific species (*Centaurea solstitialis*[87] and *Triadica sebifera*[88]).

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[81] Kraaij, T., Baard, J. A., Arndt, J., Vhengani, L., & van Wilgen, B. W. (2018). An assessment of climate, weather, and fuel factors influencing a large, destructive wildfire in the Knysna region, South Africa. Fire Ecology.

[82] Byeon, D.-h., Jung, S., & W-H., L. (2018). Review of CLIMEX and MaxEnt for studying species distribution in South Korea. Journal of Asia-Pacific Biodiversity.

[83] Kriticos, D. J. (2012). Regional climate-matching to estimate current and future sources of biosecurity threats. Biological Invasions.

[84] Kriticos, D. J., Sutherst, R. W., Brown, J. R., Adkins, S. W., & Maywald, G. F. (2003). Climate change and the potential distribution of an invasive alien plant: *Acacia nilotica* ssp. *indica* in Australia. Journal of Applied Ecology.

[85] Lu, X., Wang, L., & McCabe, M. F. (2016). Elevated CO_2 as a driver of global dryland greening. Scientific Reports.

Ni, W. L., Li, Z. H., Chen, H. J., Wan, F. H., Qu, W. W., Zhang, Z., & Kriticos, D. J. (2012). Including climate change in pest risk assessment: the peach fruit fly, *Bactrocera zonata* (Diptera: Tephritidae). Bulletin of Entomological Research.

[86] https://adaptnrm.csiro.au/wp-content/uploads/2014/08/Adapt-NRM_M2_WeedsTechGuide_5.1_LR.pdf

[87] AdaptNRM module 2: Invasive plant species and climate change https://data.gov.au/dataset/ds-dap-csiro%3A10209/details?q=alien%20species

[88] AdaptNRM module 2: Invasive plant species and climate change https://data.gov.au/dataset/ds-dap-csiro%3A8708/details?q=alien%20species

2) A proposed framework for the conservation of terrestrial native biodiversity in New Zealand including management of threats – adapting to a changing climate[89].

3) A guide to the methods, resources and assistance available for dealing with invasive species in a changing climate – Bioinvasions in a Changing World: A Resource on Invasive Species-Climate Change Interactions for Conservation and Natural Resource Management, December 2014, Prepared for The Aquatic Nuisance Species Task Force (ANSTF) and The National Invasive Species Council (NISC) By the *Ad Hoc* Working Group on Invasive Species and Climate Change[90].

E. Risk analysis on the potential consequences of the introduction of invasive alien species on social, economic and cultural values

E1 General discussion

50. While plants provide 80% of global food supply and produce 98% of the planetary oxygen, each year an estimated 10–16% of global harvest and up to 40% of global food crops are lost to plant pests. There has been a three-fold increase in the value of trade in agricultural products over the last decade to US$1.7 trillion. This is matched by plant pest losses to agricultural trade of more than US$220 billion annually[91]. These are massive socioeconomic impacts. Invasive plant pests, like fall army worm, are spreading more quickly around the globe. Pests are appearing earlier and in places where they have never been seen before, influenced by climate change, threatening to reduce both the quality and quantity of crops, reducing yields. Rising temperatures are also exacerbating water scarcity, and changing the relationship between pests, plants and pathogens.

51. The International Plant Protection Convention (IPPC) develops, (i.) international standards for phytosanitary measures (ISPMs); (ii) Commission on Phytosanitary Measures (CPM) recommendations; and (iii) implementation and capacity building activities of the 183 IPPC member countries (= contracting parties). The IPPC has over 100 standards, many of which are relevant for the protection of cultivated plants, but also extend to encompass natural flora and plant products (https://www.ippc.int/en/core-activities/standards-setting/ispms/#publications). Relevant standards include:

(a) Phytosanitary treatments and diagnostic protocols for specific pests (https://www.ippc.int/en/core-activities/standards-setting/ispms);

(b) ISPM 2 on framework pest risk analysis available at: https://www.ippc.int/en/publications/592/);

(c) ISPM 5: Glossary of phytosanitary terms; Supplement 2: Guidelines on the understanding of "potential economic importance" and related terms including reference to environmental considerations;

(d) ISPM 11 on pest risk analysis for quarantine pests (https://www.ippc.int/en/publications/639/), which also considers in its supplements pest risk analysis for Living Modified Organisms (LMOs) and determining the potential for a LMO to be a pest;

(e) ISPM 15: Regulation of wood packaging material in international trade;

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[89] https://www.doc.govt.nz/Documents/science-and-technical/sap257.pdf

[90] https://www.eli.org/sites/default/files/docs/bioinvasions_in_a_changing_world_dec_2014.pdf

[91] Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N and Nelson A 2019. The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution 434 430–439. (http://www.nature.com/natecolevol)

(f) ISPM 27: Diagnostic protocol for *Xylella fastidiosa* as regulated pest and guidelines for the prevention, eradication and containment;

(g) CPM recommendation on "Threats to biodiversity posed by alien species: actions within the framework of the IPPC" (https://www.ippc.int/en/publications/84229/);

(h) Fruit fly standards, over 23 international standards that provide guidance to establish areas pest-free of fruit flies, to determine fruit or vegetable hosts, to effectively carry out disinfestation through irradiation and cold treatments;

(i) Avocado phytosanitary measures to minimize the risk of international movement of three weevils and a moth, adopted as international standards;

(j) Fall armyworm (FAW). FAO is taking an active role in coordinating partners' activities, plans and approaches to provide sustainable solutions to the FAW challenge.

52. In addition to the above, the IPPC has a newly endorsed draft Strategic Framework for 2020-2030, in which there is a Strategic Objective – "Protect forests and the environment from the impacts of plant pests". This objective is targeted at plant pests which are invasive alien species and which can and do have a significant and devastating impact on the terrestrial, marine and freshwater environments, agriculture and forests. The IPPC standards and the IPPC framework are applied to address environmental concerns as they relate to plant biodiversity and emerging problems associated with invasive alien species that are plant pests, noting that the IPPC definition of pest includes plants that are pests (e.g. weeds). This framework is highly relevant for the Convention of Biological Diversity (CBD) and its post-2020 global biodiversity framework (GBF) to be finalized at the next Conference of the Parties to the CBD in October 2020. Recommendations to the post-2020 global biodiversity framework are as follows:

(a) A robust framework that considers plant health as a key component;

(b) A framework that highlights invasive alien species that are plant pests;

(c) A framework supported by a coherent, comprehensive and innovative communication.

E2. Existing cases of the impacts of invasive alien species on social, economic and cultural values

Key reviews

53. A special issue on "The human and social dimensions of invasion science and management" has recently been published in the Journal of Environmental Management vol 229, including 18 articles covering existing research and case studies from all over the world: Nepal, Chile, Guam, Madagascar, indigenous Australia, South Africa, La Reunion (see https://www.sciencedirect.com/journal/journal-of-environmental-management/vol/229/suppl/C). A study[92] also broadly reviewed this issue across the world.

54. This special issue includes a review paper[93] which concludes that invasive alien species are a well-recognized driver of social-ecological change globally, however impacts on livelihoods and human well-being are less well understood in terms of effects (benefits and costs) and yet this is important for guiding policy formulation and management. Slightly less than half (48%) of species studied had both substantial positive and negative impacts on local livelihoods (e.g. Australian *Acacia* spp. species; *Camelus dromedarius*; *Lantana camara*; *Prosopis* spp.), with 37% inducing mainly costs (*Chromolaena odorata; Lissachatina fulica; Opuntia stricta*) and 16% producing mainly benefits (*Opuntia ficus-indica; Acacia* spp.). Some species, such as *Acacia dealbata*, fell into different categories depending on the

[92] Pfeiffer, J.M. and Voeks, R.A., 2008. Biological invasions and biocultural diversity: linking ecological and cultural systems. Environmental Conservation, 35(4), pp.281-293.

[93] Shackleton, R.T., Shackleton, C.M. and Kull, C.A., 2019. The role of invasive alien species in shaping local livelihoods and human well-being: A review. Journal of environmental management, 229, pp.145-157.

social-ecological context. Key benefits or services included the provision of fuelwood, fodder, timber and food products for local households communities and to a lesser extent supporting and regulating services such as soil improvement and shade. A number of species also provided cultural services such as recreation and spiritual values and provided many people with an opportunity to earn a cash income. However, invasive species also harm livelihoods and increase vulnerability through encroaching on land and reducing mobility or access. They can also decrease the supply of natural resources used by households and reduce agricultural production (livestock and/or crops) which can result in losses of income and increased vulnerability. Furthermore, some invasive species were seen to have negative implications for human health and safety and reduce the cultural value of landscapes. Economic impacts on livelihoods as a result of invasive species were highly variable and very dependent on the social-ecological contexts. These negative implications can reduce resilience and adaptive capacity of households and communities thus increasing their vulnerability to change.

Regional examples

55. Sweden: Invasive alien species like *Lupinus polyphyllus*, *Rosa rugosa*, *Heracleum mantegazzianum* and *Impatiens glandulifera* have impacts on significantly biologically (contain half the nationally important threatened species) and culturally important (called "kulturlandskap" "cultural landscape") meadows and pastures that have a special flora and fauna as a result of traditional agricultural practices that are increasingly being abandoned. They form the traditional Swedish countryside, scenery that is homely and picturesque. Some socioeconomic impacts of biodiversity loss are recognized and honey producers lose quality and value from the modified pastures. Plant invasive species form monocultures replacing the diversity of natural, less pretentious flora which will totally change the scenery. The general cultural impact of changing scenery on average member of the population is hard to measure.

56. Australian aborigines: Social and cultural impacts of weeds on aboriginal land, impacts on indigenous foods and other cultural values were posted on the Online Forum. Aboriginal rangers are tackling the problem (https://ictv.com.au/video/item/1610). Grasses brought in for grazing agriculture where they are considered of value are significantly affecting native food sources and species through dense vegetation and altered fire regimes. "Storylines" and "Songlines" in indigenous culture can be relevant for understanding of the socioeconomic impacts of invasive alien species in local communities and indigenous livelihoods. For example, there are storylines on how the dingo (wild dog) spread through indigenous communities thousands of years ago and modified their landscapes leading to loss of some native species. More modern examples include the arrival of feral cats and their impacts but also their use as a novel food source, similarly for pigs and water buffalo (and more recently feral cattle), which are both feral animals in Australia that are now very important to indigenous culture. Indigenous communities adapt to use some invasive alien species as novel food source including pigs and water buffalo (and more recently feral cattle). Both negative and positive cultural importance needs to be understood and quantified[94],[95],[96],[97]. Many studies have also focussed on the national feral camel culling program in central Australia[98],[99],[100].

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[94] Urry, J., 1979. Beyond the frontier: European influence, aborigines and the concept of 'traditional'culture. Journal of Australian Studies, 3(5), pp.2-16. (https://www.tandfonline.com/doi/abs/10.1080/14443057909386796?journalCode=rjau20)

[95] Symanski, R., 1994. Contested realities: feral horses in outback Australia. Annals of the Association of American Geographers, 84(2), pp.251-269.(https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8306.1994.tb01737.x)

[96] Trigger, D.S.2008. Indigeneity, ferality, and what 'belongs' in the Australian bush: Aboriginal responses to 'introduced' animals and plants in a settler‐descendant society. Journal of the Royal Anthropological Institute, 14(3), pp.628-646.

57. South Africa: The constitution ensures everyone has the right to an environment that is not harmful to their health or well-being, providing a basis for socioeconomic consideration. The National Environment Management Biodiversity Act – Alien Invasive Species Regulations states that risk assessment should include key economic, social and ecological considerations (without defined modalities) to guide a decision for import permits for exotic species. Some studies suggest environmental and socioeconomic impacts are significantly correlated e.g. water hyacinth[101],[102].

Invasive alien species examples

Bamboo (*Bambusa vulgaris*) hinders the regeneration of native wet montane vegetation in the Blue and John Crow Mountains National Park in Jamaica, as well as other forested areas across the island. There is however a thriving bamboo industry for its construction value as a relatively cheap and accessible material [103] and for soil conservation (commonly bordering riverbanks to stabilize the soil), and important for a traditional musical instrument called "Benta".[104] Bamboo has also found its way into Jamaican superstition[105]. The longstanding and common acceptance of bamboo as a part of the Jamaican cultural landscape has presented resistance to evidence it is an invasive species in Jamaica.

58. *Prosopis* & *Acacia* (in Africa and India) cause major socioeconomic impacts on rural indigenous communities but have also led to adaptation in these communities in the use of these plants to create new industries. This shows how local communities will find value in intractable invasive alien species, but this can also lead to greater invasive alien species environmental impacts and ecosystem degradation in the longer term. For understanding how best to manage invasive alien species, it is important to understand these local community adaptations[106],[107],[108],[109],[110],[111],[112].

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[97] Robinson, C. and Wallington, T., 2012. Boundary work: engaging knowledge systems in co-management of feral animals on Indigenous lands. Ecology and Society, 17(2).

[98] Vaarzon‐Morel, P. and Edwards, G., 2012. Incorporating Aboriginal people's perceptions of introduced animals in resource management: insights from the feral camel project. Ecological management & restoration, 13(1), pp.65-71. (https://onlinelibrary.wiley.com/doi/full/10.1111/j.1442-8903.2011.00619.x)

[99] Kaethner, B., See, P. and Pennington, A., 2016. Talking camels: a consultation strategy for consent to conduct feral camel management on Aboriginal-owned land in Australia. The Rangeland Journal, 38(2), pp.125-133.(http://www.publish.csiro.au/RJ/RJ15076)

[100] Vaarzon-Morel, P., 2017. Alien relations: Ecological and Ontological Dilemmas Posed for Indigenous Australians in the Management of "Feral" Camels on their Lands. University of Toronto Press. (https://ses.library.usyd.edu.au/handle/2123/20842)

[101] Nentwig W, Bacher S, Pyšek P, Vilà M & Kumschick S (2016) The generic impact scoring system (GISS): A standardized tool to quantify the impacts of alien species. Environmental Monitoring and Assessment 188:315

[102] Rumlerová, Z., Vilà, M., Pergl, J. Nentwig, W. and Pyšek, P. (2016) Scoring environmental and socioeconomic impacts of alien plants invasive in Europe. Biological Invasions.

[103] Rashford, J. The Past and Present Uses of Bamboo in Jamaica. Economic Botany.

[104] Senior, O. 2003. Encyclopedia of Jamaican Heritage. Twin Guinep Publishers.

[105] Bengry, R. P. 1950. Moonshine and Science. Natural History Notes , vol.IV, No.42, pp. 111

[106] Fagg, C.W. and Stewart, J.L., 1994. The value of Acacia and Prosopis in arid and semi-arid environments. Journal of Arid Environments, 27(1), pp.3-25.

[107] Berhanu, A. and Tesfaye, G., 2006. The Prosopis dilemma, impacts on dryland biodiversity and some controlling methods. Journal of the Drylands, 1(2), pp.158-164.

[108] Cunningham, P., Nicholson, C., Yaou, S., Rinaudo, T., Australia, N. and Harwood, C., 2008, March. Utilization of Australian acacias for improving food security and environmental sustainability in the Sahel, West Africa. In Proceedings of the international symposium on 'underutilized plants for food, nutrition, income and sustainable development

[109] Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M. and Adeka, R., 2009. Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity, 10(2-3), pp.33-50

59. Water hyacinth (West African countries) heavily impacts water navigation for local fishermen and reduces local fish harvests and hence negatively impacts food security for the already financially-stressed families. A Nigerian, *Achenyo Idachaba*, established a local company that harvests water hyacinth and uses the dried stalks to make local crafts, which have been displayed in international galleries. She also won the 2014 Carter Women's initiative global prize for her work. More about her work is accessible at https://www.cartierwomensinitiative.com/candidate/achenyo-idachaba.

60. Typha grass (*Typha latifolia* - Northern Nigeria). The government use of heavy machinery to control its growth was counterproductive and interviewed community leaders complained they were not involved. Now, the Nigeria Conservation Foundation (a non-profit) is spearheading projects to encourage harvesting the plants and using them in making charcoal, an alternative income source and control method.[113]

61. Freshwater crayfish (*Procambarus clarkii* – Eastern China). Popular food in Eastern China, farmed over 92,000 km^2, which is producing more than 110,000 tons with the value of 45 billion Yuan per year. This aquaculture employed 500,000 people in Jiangsu Province in 2017. While in Yunnan Province in southwestern China, the crayfish is not recognized as an invasive alien species, it causes damage to rice terraces in the Honghe Hani Rice Terraces, a UNESCO World Heritage landscape. The local people who do not like to eat it have no effective control strategy. Assessing the potential economic, environmental and cultural risks of invasive alien species should take into account the special local production and lifestyle. *Procambarus clarkii* was introduced in Egypt in the early 1980s for commercial aquaculture. It rapidly expanded in all freshwater aquatic ecosystems including streams, ponds, and marshes and covered the whole Nile Delta region in the north, and to near Aswan in the south. Possible management options include the elimination or reduction of populations via mechanical, physical, chemical or biological methods. But eradication in River Nile is too late in Egypt.

62. Lake Qarun in Egypt was subjected to the problem of isopod cymothoids (Crustacea: Isopoda; Cymothoidae) which are parasites of fish. Invasion began in 2015, and the parasite gradually propagated reaching a catastrophic invasion causing fish mass loss, great marketing problems and gradual decline of fish stock that consequently lead to economic losses, in addition to the great impact on local fishermen's livelihood. This invasive species entered Lake Qarun through transportation process of fish fry from the Mediterranean Sea to the lake. Treatment and control of crustacean parasites, especially isopods, are a complicated process and the use of chemical therapeutics is illogical and difficult to be applied when the infestation is epidemic in large water basin as in Lake Qarun. On the other side, although biological controls are not easy to apply, they are considered as one of the promising ways to control such infestation. The possibility of using marine crabs as a biological control agent against isopods could be useful. Therefore, General Authority of Fisheries Resources Development (GAFRD) decided that the best way to control this infestation is by preventing introduction of any fish fry to the lake in next three years until the infestation is removed and introduce only prawn species since the isopod does not infect the prawn shrimp.

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[110] Sato, T., 2013. Beyond water-intensive agriculture: Expansion of *Prosopis juliflora* and its growing economic use in Tamil Nadu, India. Land use policy, 35, pp.283-292

[111] Baka, J., 2014. What wastelands? A critique of biofuel policy discourse in South India. Geoforum, 54, pp.315-323.

[112] Bekele, K., Haji, J., Legesse, B. and Schaffner, U., 2018. Economic impacts of *Prosopis* spp. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data. Journal of Arid Environments, 158, pp.9-18.

[113] Borokini T.I and Babalola F.D. (2012). Management of invasive plant species in Nigeria through economic exploitation: lessons from other countries. Management of Biological Invasions 3(1): 45-55.

E3. Actual and potential risk analysis and other relevant methods for preventing/limiting the impacts of invasive alien species on social, economic and cultural values

63. Risk analysis needs to consider both the socioeconomic impacts posed by a species and considerations arising from its management separately when prioritizing species for management. A study [114] concluded that attempts to quantify socioeconomic impacts in monetary terms are unlikely to provide a useful basis for evaluating and comparing impacts of invasive alien taxa because they are notoriously difficult to measure, they are often context-dependent, and important aspects of human well-being are ignored. They identify different constituents of human well-being may be affected: security; material and immaterial assets; health; and social, spiritual and cultural relationships. They go on to propose the SEICAT process, which provides a mechanism to assess each of these in turn[81].

64. However, other contributors highlighted recent developments in the methods to monetize the impacts of IAS which offer scope to improve the use of cost-benefit analysis and related economic methods in this context.[115],[116]

65. A different approach is needed to assess the sociological impacts of management. A study[117] proposed a method to assess the overall feasibility of management, with separate sub-categories covering effectiveness, practicality, social acceptability, wider environmental impact, and cost. This combination of methods, assessing the social implications of a species as part of wider risk assessment, and the social acceptability of management as part of risk management, can be combined in a process of risk analysis. This combined approach allows the prioritization of species and their management based on a rapid assessment in non-monetary terms. While more detailed economic cost-benefit analyses can be used to assess individual cases, we need rapid methods to prioritize action given the large number of species and invasions that we are currently experiencing.

66. There is also social impact assessment which offers a structured process of identifying, evaluating and addressing social costs and benefits. It has potential value for enabling meaningful public participation in planning and as a key component of integrated assessments of management options[118].

67. What is still lacking is well documented socioeconomic, cultural and community well-being semi-quantitative criteria on which to, not only, evaluate impact but also to evaluate effectiveness of applied risk management options. For example, if a weed invades and suppresses a culturally important indigenous food plant or iconic species, how does this reduce the capacity of that community to be self-sustaining or lead to loss of community cultural values? Also, what are the target invader or site-based management thresholds needed to be achieved to adequately suppress that threat?

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[114] Bacher, S., Blackburn, T. M., Essl, F., Genovesi, P., Heikkilä, J., Jeschke, J. M., Jones, G., Keller, R., Kenis, M., Kueffer, C., Martinou, A.F., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Roy, H.E., Saul, W-C.,Scalera, R., Vilà, M., Wilson, J.R.U., Kumschick, S. (2017). Socio-economic impact classification of alien taxa (SEICAT). Methods in Ecology and Evolution, 1–10. (https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/2041-210X.12844)

[115] Eiswerth, M., Lawley, C. and Taylor, M.H., 2018. Economics of Invasive Species. In Oxford Research Encyclopedia of Environmental Science.

[116] Epanchin-Niell, R.S., 2017. Economics of invasive species policy and management. Biological Invasions, 19(11), pp.3333-3354.

[117] Booy, O., Mill, A.C., Roy, H.E., Hiley, A., Moore, N., Robertson, P., Baker, S., Brazier, M., Bue, M., Bullock, R. and Campbell, S., 2017. Risk management to prioritise the eradication of new and emerging invasive non-native species. Biological Invasions, 19(8), pp.2401-2417. (https://link.springer.com/article/10.1007/s10530-017-1451-z)

[118] Crowley, S.L., Hinchliffe, S. and McDonald, R.A., 2017. Invasive species management will benefit from social impact assessment. Journal of Applied Ecology, 54(2), pp.351-357.

68. Risk assessment tools have also been developed by the GIASI Partnership (http://giasipartnership.myspecies.info/en/simpletaxonomy/term/14701), and the IUCN Invasive Species Specialist Group (http://www.issg.org/risk_assessment_resources.htm). The standard IPPC Pest Risk Analysis process can also be found at https://www.ippc.int/en/core-activities/capacity-development/guides-and-training-materials/guides-and-training-materials/pest-risk-analysis/. See also Anderson et al. 2004[119]. There are also approaches for assessing many species at the same time in terms of understanding the threats they pose to new regions based on community similarity and probability of arrival e.g. based on level of trade[120].

E4. Future needs of defining, measuring and managing invasive alien species impacts on social, economic and cultural values

69. The extensive accumulated knowledge and data over the past 30 years can be used to 'define', 'measure' and 'quantify' accurately the impacts of alien invasive plants on 'socioeconomic and cultural values and the well-being of indigenous and local communities. However implementable and successful control solutions are lacking. Significant progress has been made in biological control, however maintaining sustainable biocontrol agent populations over time can be challenging. Chemical control is still expensive and environmentally harmful, though new molecules show better ecotoxicological profiles. There are several key questions for better management:

(a) *How can we guide and prioritize actions to better focus on achievable management goals?* Too often the priorities for species listing or management are based on the scale and likelihood of the impact, without considering the feasibility of management. The feasibility of management depends on political will, the availability of acceptable techniques, knowledge and a legal framework for implementing control, the scale of the problem, the availability of well-trained teams to perform the control, and financial resources allocated to management as a long-term investment for invasive alien species management;

(b) *What is the best model to invest resources in prevention, eradication or long-term management?* Prevention can of course be highly cost-effective but is often ineffective due to weak enforcement systems and lack of motivation or commitment. Moreover, the national or local authorities need to be informed on evidences of biological invasions to determine priority actions. Preventing a problem that has not yet occurred requires a strong self-motivation at all levels, but investment is still needed for eradication and ongoing management;

(c) *All management approaches need resources, but how do we optimize this process in different environments and for different taxa?* Investments on long-term management often lead to poor outcomes. Prioritising management actions through risk analysis should provide a more cost-effective and transparent balance of management across prevention, eradication and on-going management activities. More rigorous monitoring, evaluation and recording of control programs would improve learning and lead to improved long-term efficiency;

(d) *What are the ecological criteria to switch species management goals from prevention to eradication to long-term management?* Too often we see programmes that misapply these objectives, failing to prevent and eradicate when it is still feasible, while investing in long-term species management;

(e) *How can the scientific community support the production of new and refined tools for management?* Practitioners need more species-specific control methods, more cost-effective ones and

[119] Andersen, M.C., Adams, H., Hope, B. and Powell, M., 2004. Risk assessment for invasive species. Risk Analysis: An International Journal, 24(4), pp.787-793.

[120] Paini, D.R., Sheppard, A.W., Cook, D.C., De Barro, P.J., Worner, S.P. and Thomas, M.B., 2016. Global threat to agriculture from invasive species. Proceedings of the National Academy of Sciences, 113(27), pp.7575-7579.

new technologies to achieve this. For invasive plants, biological control has been the most effective solution, making great progress in the past 20 years, reducing the problems of non-target effects. Concerns remain for indirect effects of biocontrol agents on local food webs. Greater investment in biopesticide development may be merited. Other opportunities include the development of species-specific toxins, self-reporting and resetting traps, and the use of gene and sterile release technologies;

(f) How can the scientific community help practitioners manage effectively at large scales? There are numerous examples of successful eradications or removals, but most are based on very small areas. Working at large scales brings new challenges, how can we learn from successful examples, can we develop new species-specific cost-effective control methods and new technologies to increase the scales at which management can be effective?

(g) *How do we use our understanding of ecology and species dynamics to guide more effective management at scale?* Future research should focus on developing appropriate effective tools for managing invasive alien species and informing effective management policy.

70. Information on impacts, whether they are economic, biodiversity or social, is needed together with science that combines this with information on management feasibility and economics to guide effective management strategies. There is also an urgent need of many countries to carry out studies immediately to identify first which species are invasive, assess the impact of each species on the local livelihood and consider what management is feasible. Efforts made by the local communities for managing invasive alien species have not always been well informed by scientific research. In summary, future research should focus on generating knowledge to inform management.

Cultural values

71. It is important to understand the role of cultural values and perspectives in the management of invasive alien species. In New Zealand, Māori-sourced indigenous knowledge referred to as mātauranga Māori, has an increasingly important role in environmental management, including protection of biological heritage from invasive alien species. The New Zealand government is actively exploring with Māori how to include mātauranga Māori into the national work on invasive alien species management. This is signalled as a clear priority in the country's Conservation and Environment Science Roadmap, as a whole (https://www.mfe.govt.nz/about-us/our-policy-and-evidence-focus/conservation-and-environment-science-roadmap) and mātauranga Māori approaches are central to several of our research programmes focussed on fighting invasive alien species , such as the pathogens causing kauri dieback and myrtle rust. It is now also common-place for Māori to be involved in governance of invasive alien species management programmes where taonga (treasured, sacred) species are at risk.[121]

Invasive alien species examples

72. *Prosopis* (mesquite) in Western Asia, Africa and in India. Dense stands of mesquite, often deliberately introduced for fodder, spreads all over and totally changes the ecosystem in many areas, severely lowering the water table in the soil causing the collapse of the grass that creates the pastures. The pods can be used as source of fodder for the goats and the wood is used as a fuel depending on the context of each region and local livelihoods. Within few years there is no fodder left and pastoralists have to move becoming nomads. This inevitably creates conflict and dismay for local communities. The process, the causes and the consequences are well understood, however no solution has been proposed for solving this problem. At least, spread of *Prosopis* is mapped.

[121] Lambert, S., Waipara, N., Black, A., Mark-Shadbolt, M. and Wood, W., 2018. Indigenous biosecurity: Māori responses to kauri dieback and myrtle rust in Aotearoa New Zealand. In The Human Dimensions of Forest and Tree Health (pp. 109-137). Palgrave Macmillan, Cham. (https://link.springer.com/chapter/10.1007%2F978-3-319-76956-1_5)

73. Pine wood nematode (PWN - *Bursaphelenchus xylophilus*) causes the economically and environmentally significant 'pine wilt disease' in species of pine (*Pinus* spp.). PWN is native to North America and is vectored through parallel introductions of the wood-inhabiting North American longhorn beetle *Monochamus*; it has spread to Japan, China and Korea and then Europe (Portugal) in 1999 and now threatens the rest of Europe. Local species of *Monochamus* can also be vectors for the disease. PWN is not only an important pest for forestry production, but also alpine forests causing increased erosion. In Korea, the disease has cost over US$600 million in 20 years with additional ecological and social impact. IPPC ISPM 15 (wood packaging) has helped stem the spread. This example helps understand how future impacts from forestry pests can be risk assessment quantified and managed.

III TOWARDS GLOBALLY HARMONIZED MEASURES TO MANAGE INVASIVE ALIEN SPECIES FOR ACHIEVING AICHI BIODIVERSITY TARGET 9, AND FACILITATION OF THE IMPLEMENTATION OF THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

74. This section describes how the findings of the Online Forum help the way forward for Parties to take actions to achieve Aichi Biodiversity Target 9 under the current circumstances and beyond 2020 with the Post-2020 Global Biodiversity Framework. Although the process of setting the Post-2020 Global Biodiversity Framework is on-going, the risk on biodiversity posed by invasive alien species may continue to be Parties' concerns, and the negative impacts may also be anticipated to increase due to the continuing high amount of trade, transport and development actions. The AHTEG may need to consider how to proactively accelerate the implementation of globally harmonized measures. If any new tools need to be developed, their specification and scientific justification are expected to be provided by the AHTEG.

Tools for safe international trade (SPS measures)

75. The Online Forum found that Parties, regardless of their positions in economic development, have taken actions to prioritize and manage the already established and negatively impacting invasive alien species with many examples. While applying preventive measures on introduction of alien species complying with the international standards throughout the stages of pre-border, at the border and post-border areas, implementation is not always simple, due to the required risk analysis and import regulations to be in place. Under the Agreement on the Application of Sanitary and Phytosanitary Measures (the "SPS Agreement") of the World Trade Organization and its recognized international standards, the standards continue to serve methods and tools to ensure safe international trade. Application of the SPS measures may require further promotion to prevent introduction of, and control or eradicate invasive alien species. The CBD guidance on invasive alien species also fills the gaps among the existing standards, for example, measures to avoid unintentional introduction of invasive alien species associated with trade in living organisms (annex I to decision 14/11) in order to minimize the impacts of invasive alien species on biodiversity.

Pathways management

76. Regarding the management of pathways by applying appropriate pathway measures, the experiences posted on the Online Forum are varied and relatively limited compared to the cases on species-specific invasive alien species management. There was only limited information presented during the Online Forum regarding the management of the pathways (transport-stowaway, transport-contaminants, escapes, corridor) considered by the Conference of the Parties (decision VIII/27), such as: (i) inter-basin water transfer and navigational canals; (ii) international development assistance; (iii) emergency relief, aid and response; (iv) air transport; (v) tourism; and (vi) scientific research among Parties. The AHTEG may need to follow up the Online Forum, taking into account the emerging impacts from the environment (climate change, natural disasters, and land use changes), and increasing rapid transport and trade transactions via e-commerce. With regard to management, in particular prevention, of ship-mediated transport, there is a global regulatory framework under the International Maritime Organization on ballast water and biofouling. The Inter-agency Liaison Group on Invasive Alien Species

informs on the transport risks of living organisms to the ECOSOC Sub-committee of Expert on the Transport of Dangerous Goods towards globally harmonized measures on transport of living organisms. With such examples, it is important to continue to advise on international regulatory bodies to include invasive alien species into each of the risk management method or tools to be developed under the relevant international organizations.

Surveillance / information sharing

77. Monitoring, reporting and sharing information on invasive alien species, whether they are regulated or not regulated, are advanced in many Parties with expertise and resources. The research and data-sharing on potentially invasive alien species with known impacts on biodiversity and socioeconomic and cultural values are moving forward. However, such information sharing is still limited in developing countries where often additional environmental pressures (e.g. climate change, natural disaster and land use changes) are high and resources for the effective management (e.g. integrated pest management) are not sufficient. Information is essential for applying analytical tools (risk analysis, cost-benefit/cost-effectiveness analysis, establishment/spread/population modeling) and designing effective actions to minimize the impact of invasive alien species. The AHTEG may need to consider how to facilitate information sharing, overcoming the potential of trade dispute, as it ensures global benefits arising from protection of biodiversity from invasive alien species.

Decision support tools

78. Under the existing national policy and priority, decision on prioritizing invasive alien species management requires compelling evidence of its benefit and effectiveness. Although decisions to take cost-effective measures have been highlighted repeatedly at the Conference of the Parties and other CBD processes, available data, knowledge and technology to undertake complex analysis on integral costs in social, economic, environmental, agricultural and various other aspects appeared to be a challenge. There are a number of cases applying cost-benefit/cost-effectiveness analysis prior to management. The Online Forum also exchanged information on broad range of risk analyses, e.g. pest risk analysis, weed risk assessment, how to consider the consequence on cultural values, among others. These analytical methods may provide a basis for policy makers to prioritize decisions based on multiple criteria, not just economics. However, currently there is no accepted, comprehensive method for this purpose. The AHTEG may need to clarify how to use the various analytical tools and how to communicate the result of analyses with policy makers and the public in order for well-informed decision-making.

Existing capacity of Parties

79. The capacity to apply existing tools, including capacity evaluation tools on the ground varies from one country to another. The efficiency with which existing tools are used depends on the readiness of Parties to use the tools, taking into account that scientific analysis requires knowledge in taxonomy, ecology, genetics, pathology, geography and some tools are in constant development with continuing research. The AHTEG may need to elaborate the requirements of knowledge and information, facility and equipment as well as skills to use the tools.

80. The AHTEG may also need to identify what type of capacity building activities are important for the effective application of tools in some recourse limited countries and how international collaboration can be facilitated to transfer and maintain the technical and technological skills in the countries where capacity development needs are high.

Summary on tools to be further developed in invasive alien species management

81. The international regulatory framework related to invasive alien species is distributed across broad sectors. Within the national government, ministries/agencies for: (a) environment, (b) agriculture, forestry and fisheries; (c) land, air and sea transports; and (d) finance and Customs are responsible for application of the tools mentioned in this document. Obviously, new tools may be required to effectively

communicate on the issue of invasive alien species among the relevant ministries/agencies and explanatory guidance how to apply existing tools to manage invasive alien species can help effective implementation. The emerging risks associated with e-commerce, and other risk fluctuating factors, such as climate change, natural disasters, and land use changes need to be explained to Parties.

82. In summary, the Online Forum revealed the tools to be newly developed, as follows:

(a) Explanatory guide on how to apply the SPS measures for invasive alien species management to conservation authority and implementers;

(b) Multi-criteria decision support guidance for policy makers, referring to recommended analyses on biological invasion risk, cost and benefit/efficiency, management feasibility, and the potential impact on biodiversity and cultural values;

(c) A communication guide on invasive alien species as environmentally hazardous articles to raise awareness among the officials in agriculture and transport sector and Customs office, as well as the public;

(d) Explanatory guide for scientific community to share the data and data tools on invasive alien species;

(e) Training guide to fulfill the capacity required for the application of tools, taking into account the research requirement to apply the tools to invasive alien species management; and

(f) Publication of best practices of invasive alien species management, especially on tools with advanced technologies and the required technical capacity to apply such tools.

83. The Ad Hoc Technical Expert Group may scrutinize the identified existing tools and practices by the Online Forum to further specify the deliberation of possible new tools (advices or element of technical guidance) indicated in paragraphs 82 (a)-(f) for achieving Aichi Biodiversity Target 9 and beyond.

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