

The Discussion Forum on development of IAS management tools and guidance began on 1 May 2019 with a discussion of Cost-Benefit Analysis. Over the first 10 days, it received 121 contributions from around the world, providing commentary and examples of the use of this and related methods. The discussion was structured into a number of threads asking for views and evidence on different aspects of this issue. This report summarises the contributions received by 10 May 2019 (9:00 GMT)

- **Remit of the Discussion - Decision making in the marine environment**

Contributions were received from a number of contributors highlighting the problems faced when managing species in the marine environment. In particular they emphasised 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 supported.

- **What do we mean by analysis of costs and benefits?**

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:

- Cost-benefit analysis - using purely monetary values to assess both the costs and benefits of a species or management action.
- Cost-effectiveness analysis, contrasting the costs of implementing a programme with the benefits measured in non-economic terms, for example the number of a threatened species saved.
- Multi-criteria methods – assessing a wide range of different criteria, often measured in different currencies to prioritise amongst a variety of different available options. For example including the public acceptability, humaneness and wider environmental impacts of management proposals alongside economic costs.
- 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.
- Risk management – a process of assessing the feasibility and effectiveness of management. In some circumstances this may also be called Impact Management.
- Risk Analysis – a term referring to the combined use of risk identification, risk assessment, risk management and associated risk communication.

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

A table describing the different costs and benefits associated with invasive alien species 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 wellbeing	social
• Impact of species on wider biodiversity	biodiversity
• Impact of species on the environment	environmental
• Impact of species on economic activity	economic

Benefit of species presence	
<ul style="list-style-type: none"> Economic value of use of new species, for example use in agriculture 	economic
<ul style="list-style-type: none"> Addition of new species to local biodiversity 	biodiversity
<ul style="list-style-type: none"> Positive effects of new species on other species (including biological control) 	environmental
<ul style="list-style-type: none"> Beneficial effect of new species on human wellbeing 	social
<ul style="list-style-type: none"> Beneficial effect of new species on the environment 	environmental
<ul style="list-style-type: none"> Improved global conservation status deriving from the introduced species 	biodiversity
Cost of management	
<ul style="list-style-type: none"> Costs of restriction in trade, including reductions in level of trade 	economic
<ul style="list-style-type: none"> Costs of regulation of trade, including costs of facilitating safe trade 	economic
<ul style="list-style-type: none"> Costs of interception/inspection 	economic
<ul style="list-style-type: none"> Welfare impact of management (vertebrates) 	animal welfare
<ul style="list-style-type: none"> Costs of surveillance 	economic
<ul style="list-style-type: none"> Costs of removal 	economic
<ul style="list-style-type: none"> Costs of maintaining contingency capability 	economic
<ul style="list-style-type: none"> Social acceptability of management 	social
<ul style="list-style-type: none"> Wider environmental impacts of management 	environmental
Benefit of management	
<ul style="list-style-type: none"> Reduced risk of future invasion and associated costs 	multiple
<ul style="list-style-type: none"> Reduced current impacts 	multiple
<ul style="list-style-type: none"> Reduced future impacts 	multiple

Contributions highlighted a number of points related to these costs and benefits

- The lack of available information on which to base an assessment of economic costs in many regions.
- Most analyses and decisions only consider a small proportion of the costs and benefits described in this list.
- The importance of including non-economic measures such as biodiversity and public acceptability in decision making.
- Difficulties in defining costs and benefits for species occurring both in the wild and in domestic production, highlighting the problems associated with aquaculture.
- The need to include environmental as well as economic impacts in decision making.
- The need to consider prevention as well as the management of species once they have established
- That similar categories may be applied to pathways as well as species, of relevance to pre-border control and prevention.

What Decisions are Informed by These Analyses?

A variety of different types of decision were described in posts or attached papers. The choice of appropriate methods varied between each. These included:

- Demonstrating economic impact, often required to illustrate the importance of an issue or the need to manage.
- Showing a net economic benefit of management - often required to gain support for a management action.
- Optimising a management approach – determining the most cost-effective way to implement a programme – with examples provided in relation to surveillance or inspection.
- Prioritisation – choosing from a wide range of options (species, pathways, management alternatives) to best direct cost-effective management.

Availability of Databases

Contributors highlighted the availability of existing databases and initiatives which can inform a number of these costs and benefits. These include:

- Impact of species on wider biodiversity and the environment - existing EICAT initiative (Hawkins et al 2015) and GISS (Nentwig et al 2016)
- Impact of species on human wellbeing – existing SEICAT initiative (Bacher et al 2017)
- Species Risk assessments – a range of regional and national programmes and databases were identified. (Risk Assessments, Belgium, EU, UK)
- Cost of Eradication. A range of studies and databases describe the costs of successful eradications worldwide. (Brockerhoff et al 2010, Gardener et al 2010, Holmes et al 2015, 2016, Howald et al 2007, Martins et al 2006, Rejmanek and Pitcairn 2002, Robertson et al 2017, Gerda website)

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

- Risk Assessment - There is scope to collate these and make them more readily available, but the need for standardised metadata and quality control was highlighted (Roy et al 2018)
- Impacts of Species - a suggestion to extend the field "IsInvasive" in the GRIIS checklists (Pagad et al 2018). Here, the notion between current and potential impact becomes important. Currently the process is to provide evidence of impact to flag it as invasive = when it's already too late to act. Perhaps it's more proactive to include potential impact in these checklists.
- Wider data on the costs of management – a need for more standardised information on the practical costs of management, including prevention and ongoing management.

Examples of the use of cost and benefit analysis to support IAS management.

Examples were provided of the use of cost-benefit analyses to support decision making from a number of regions including the Caribbean (Daigneault et al 2014), Africa (Wise 2007), Europe (Reyns et al 2018) and Australia (Nordblom et al 2001).

Examples of cost-effectiveness analyses, used to assess or optimise the effectiveness of management approaches were also highlighted. (Blignaut et al 2007, Keller et al 2008, Merel et al 2008, Epanchin-Niell 2017, Kraaij et al 2017)

As well as providing links to existing databases, papers describing the methods and standards for risk assessment were provided (Roy et al 2018).

Examples of the use of multi-criteria methods to assess risk management were provided (Booy et al 2017, Zengeya 2017)

Studies were also provided that assessed the social consequences of management (Creed et al 2017)

Studies also described the costs of species presence (Bradshaw et al 2016, Hoffman and Broadhurst 2016, Economic Impacts websites)

Descriptions of national approaches to support decision making

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

Norway described how they conducted Cost-Effectiveness analysis of mitigation measures as they often lack benefit estimates. Government guidelines for CBA (and CEA) 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.

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 EEI, 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.

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.

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 prioritisation was provided (Booy et al 2017)

In Australia they have been undertaking successful environmental IAS 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 SMART management goals. (Carwadine et al 2012)

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.

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)

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

References and Links

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.

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).

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.

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

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

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.

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.

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

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

Economic Impact From Selected Noxious Weeds in Oregon

<https://www.oregon.gov/oda/shared/documents/publications/weeds/ornoxiousweedeconomicimpact.pdf>

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.

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.

Gerda website. <http://b3.net.nz/gerda/index.php>

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.

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.

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.

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.

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.

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.

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

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.

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.

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.

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.

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).

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

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.

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.

Risk Assessments Belgium <http://ias.biodiversity.be/species/risk>

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

Risk Assessments UK <http://www.nonnativespecies.org/home/index.cfm>.

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

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.

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

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*.

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.

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.