Glossary - A conceptual framework for prioritization of invasive alien species for management according to their impact

Modified from Nentwig et *al.* 2010 and Kumschick et *al.* 2012

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Impact criteria for assigning alien taxa to different categories in the classification scheme

Twelve mechanisms have been identified by Nentwig et *al.* 2010 and Kumschick et *al.* 2012, by which alien taxa may cause environmental or socio-economic impacts in areas to which they have been introduced (Table 2). The categories for environmental changes are hybridization, competition, transmission of diseases to wildlife, herbivory/toxicity, predation, and ecosystem effects in general. The categories for socio-economic impacts include agriculture, animal production, forestry, infrastructure, human health and human social-life.

Changes can be **negative** or **positive**. Changes in the negative direction denote a decrease in an attribute of ecosystem function, native biodiversity or sio-economic benefits compared to the state before the IAS was introduced and can range from no changes (score 0) to the maximum reduction possible (score 5). Positive effects can occur in systems previously altered by human-induced disturbance, e.g. alien species, land-use change, pollutants, eutrophication etc., but where an invader can fulfil some or many of the functions that previously existed or were fulfilled by species before perturbation. Thus, these scores can also range from very low changes (score 0) to the complete restoration of an expected, pre-invasion state of system functioning (score +5). Furthermore, positive effects can occur if an invasive species enhances a function still provided by other resident species.

Please note that "positive" and "negative" do not denote human values, but relate to the direction of environmental or socio-economic change after invasion relative to the pre-invasion state of the system: "positive" indicates changes towards the pre-invasion state, "negative" changes away from the pre-invasion state. Because a species might simultaneously cause positive and negative changes within the same category, but through different mechanisms, Nentwig et *al.* 2010 and Kumschick et *al.* 2012 score these positive and negative changes separately. Furthermore, it is possible that a stakeholder values positive and negative changes differently, so by keeping them separate, the categories might also be weighted differently.

Table 1: Ecological impact criteria

Ecological Impacts

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
Herbivory/ toxicity negative	No impact known or detectable	Very low level of herbivory (animals) or toxicity (plants or animals) on at least one native species, no major damage reported	Herbivory or toxicity affecting several native species, without large impact on affected species or decline of their populations	Herbivory or toxicity affecting several native species, at least one native species declining	Herbivory or toxicity affecting many native species, several declining in population size, recorded community change reversible	Herbivory or toxicity affecting native species listed as vulnerable, endangered or critically endangered by IUCN, decline of these species, replacement or even extinction of species, recorded community change irreversible
Herbivory/ toxicity positive	No impact known or detectable	Very low level of herbivory or toxicity affecting at least one species degrading the ecosystem, no impact on performance of affected species recorded	Herbivory or toxicity affecting one or several species degrading the ecosystem, without large impact on affected species or decline of their populations	Herbivory or toxicity affecting one or several species degrading the ecosystem, at least one species declining, some/first indications that the ecosystem changes towards its historical functional state	Herbivory or toxicity affecting one to many species degrading the ecosystem, declining in population size, strong indications that the ecosystem changes towards its historical functional state	Complete re-establishment of functional state of historical ecosystem that was degraded before invasion of alien species
Competition negative	No impact known or detectable	For animals, very low level of competition with at least one native species, exploitation competition; for plants, low abundance, native species richness not declining	For animals, competition with several native species by exploitation competition, without large impact on affected species or decline of their populations; for plants, moderate abundance, decrease in native species abundance but not richness	For animals, competition with several species, interference competition, at least one native species declining; for plants, high abundance, decrease in native abundance, at least one native species lost	For animals, competition with many native species, several declining in population size, competition for food and/or space, behavioural changes in out-competed species; for plants, high abundance, strong decline in both abundance and richness of native species, native species still able to recruit	For animals, competes with species listed as vulnerable, endangered or critically endangered by IUCN, decline of these species, replacement or even extinction of species; for plants, mono-dominant/near mono-dominant, with no or very few native species remaining; limiting native species recruitment options
Competition positive	No impact known or detectable	For animals, very low level of competition with at least one native species degrading the ecosystem, exploitation competition, no impact on performance of affected species recorded; for plants, no loss in abundance or richness of native species	For animals, competition with one or several native species degrading the ecosystem by exploitation competition, without large impact on affected species or decline of their populations; for plants, small increase in abundance of native species, no increase in species richness	For animals, competition with one or several species degrading the ecosystem, interference competition, at least one species declining, some indications that the ecosystem changes towards its historical functional state; for plants, increase in abundance of native species, small increase in species diversity	For animals, competition with one to many species degrading the ecosystem, declining in population size, strong indications that the ecosystem changes towards its historical functional state; for plants, increase in abundance of native species and in species diversity	For animals, completely re-establish functional state of historical ecosystem that was degraded before invasion of alien species; for plants, increase in abundance of native species and in species diversity, including threatened native species
Predation negative (not relevant for plants)	No impact known or detectable	Predation known but negligible, no decline of native species	Predation on several abundant species, without large impact on affected species or decline of their populations	Decline of one to several native species recognized, minor change in food web structure reported	Decline of many species, indirect impact by mesopredator release, clear changes in the food web	Preys also on endemic or species listed as vulnerable, endangered or critically endangered by IUCN, local extinction

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Table 1 – *Continued from previous page*

Ecological Impacts

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
Predation positive (not relevant for plants)	No impact known or detectable	Predation on species degrading the ecosystem known but negligible, no decline of species	Predation on one or several species degrading the ecosystem, without large impact on affected species or decline of their populations	Decline of one to several native species degrading the ecosystem recognized, minor change in food web structure reported, some indications that the ecosystem changes towards its historical functional state	Decline of one to many species degrading the ecosystem, clear changes in the food web, strong indications that the ecosystem changes towards its historical functional state	Completely re-establish functional state of historical ecosystem that was degraded before invasion of alien species
Transmission of diseases to wildlife negative	No impact known or detectable	Host (plant or animal) for non-specific parasites, occasional transmission of more or less harmless diseases to one native species. No population decline in native species. If a plant, species is not a breeding ground for wildlife disease vectors	Occasional transmission of more or less harmless diseases, several native species affected. No or only minor population decline in native species. If a plant, species may be a breeding ground for wildlife disease vectors, but no more so than native plant species	Many native species affected, frequent transmission of more or less harmless diseases or harmful diseases transmitted to one native species. Minor population decline in native species. If a plant, may be a more significant breeding ground for wildlife disease vectors than native plant species	Transmits harmful diseases to several native species or more or less harmless diseases to endemic or species listed as vulnerable, endangered or critically endangered by IUCN. Moderate population decline in native species. If a plant, a major breeding ground for wildlife disease vectors, outbreaks due to species presence uncertain	Transmits harmful diseases to many species and/or species listed as vulnerable, endangered or critically endangered by IUCN by direct transmission, decline of these species or extinction. If a plant, a major breeding ground for wildlife disease, outbreaks due to species presence certain
Transmission of diseases to wildlife positive	No impact known or detectable	Occasional transmission of more or less harmless diseases to one species degrading the ecosystem; no population decline in species. Potential positive effect on health of wildlife (direct: e.g. potential medicinal species; indirect: e.g. antagonist of a health threat), but not yet reported	Occasional transmission of more or less harmless diseases, one or several species degrading the ecosystem affected. No or only minor population decline in species. Occasional, small positive effect on health of wildlife	One to many species degrading the ecosystem affected, frequent transmission of more or less harmless diseases or harmful diseases transmitted to one species degrading the ecosystem. Minor population decline in species, some indications that the ecosystem changes towards its historical functional state. Regularly small positive effect on health of wildlife, or occasional, larger positive effect on health of wildlife	Transmits harmful diseases to one to several species degrading the ecosystem. Moderate population decline in species, strong indications that the ecosystem changes towards its historical functional state. Regularly leading to larger positive effect on health of wildlife	Completely re-establish functional state of historical ecosystem that was degraded before invasion of alien species. Massive positive effect on health of wildlife caused by species
Hybridization negative	No impact known or detectable	Hybridization possible in captivity, but only rarely in the wild	Hybridization is more common in the wild, no offspring, but constraints to normal mating	Hybridization is more common, with offspring, but not fertile	Hybridization common with fertile offspring	Risk of extinction of endangered species
Hybridization positive	No impact known or detectable	Hybrids are capable of coping with degraded ecosystem process(es), e.g. shown in laboratory experiments, but no indications are found in the field	Hybrids are able to cope with degraded ecosystem process(es) in the field	Some/first indications that hybrid changes the ecosystem towards its historical functional state	Strong indications that hybrid changes the ecosystem towards its historical functional state	Completely re-establish functional state of historical ecosystem that was degraded before invasion of the hybrid species

Table 1 – *Continued from previous page*

Ecological Impacts

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
Impact on ecosystem (other than mentioned before, i.e. chemical, physi- cal or structural changes) negative	No impact known or detectable	Change in chemical (e.g. eutrophication, nutrient-cycling), physical (e.g. soil compaction, structure, hydrology) and/or structural (e.g. felled trees, burrows, disturbance dynamics) characteristics detectable, but no impact on performance of natives or successional processes	Moderate change in chemical, physical and/or structural characteristics, only slight impact on performance of natives or successional processes	Major change in chemical, physical and/or structural characteristics, change in fauna and flora and/or successional processes, reversible	Severe changes in chemical, physical and/or structural characteristics, decline of species and/or change in species composition, strong impact on successional processes, but likely to be reversible	Massive changes in chemical, physical and/or structural characteristics, endemic species and/or species listed as vulnerable, endangered or critically endangered by IUCN affected, decline of species and/or change in species composition, very strong impact on successional processes, loss of habitat characteristics, damage of sites of conservation importance, irreversible
Impact on ecosystem positive	No impact known or detectable	Change towards historical state of the ecosystem in chemical (e.g. eutrophication, nutrient-cycling), physical (e.g. soil compaction, structure, hydrology) or structural (e.g. felled trees, burrows, disturbance dynamics) characteristics detectable, but no decline of populations of species responsible for the ecosystem degradation or successional processes	Moderate change towards historical state of the ecosystem in chemical, physical or structural characteristics, only slight decline of populations of species responsible for the ecosystem degradation or successional processes	Major change towards historical state of the ecosystem in chemical, physical or structural characteristics, decline of populations of species responsible for the ecosystem degradation, major change towards historical state of the ecosystem in fauna and flora or successional processes	Severe changes in chemical, physical or structural characteristics, major decline of species responsible for the ecosystem degradation or severe change towards historical state of the ecosystem in species composition or successional processes	Complete change towards historical state of the ecosystem in chemical, physical or structural characteristics, removal of species responsible for the ecosystem degradation, re-establishment of historical habitat characteristics and successional processes

Table 2: Socio-economic impact criteria

Socio-economic Impacts

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
On agriculture negative	No impact known or detectable	Only occasional damage or yield loss to crops or plantations (e.g. or- chards), damage similar to native species; for plants, plant present, but no operational obstruction or removal/control cost	Damage or yield loss to crops common, damage or yield loss similar to native species; for plants, little operational obstruction or removal/control cost. Some trade disruptions	Regular damage or yield loss similar to native species through feeding on crops or through competition, occasional threat to stored food, losses ex- ceed impact of the native fauna and flora, sometimes reaching high levels; for plants, operational obstruction and costs to remove/manage invader are still minor. Moderate trade disruptions	Regular high damage or yield loss in fields or to stored food, fruit con- sumption; for plants, operational obstruction and costs to remove/manage invader are considerable. High trade disruptions	Complete loss of yield or destruction of fields or plantations (e.g. orchards), or of stored food by consumption and contamination; for plants, opera- tional obstruction and costs to remove/manage invader prohibit profitable agriculture on invaded land. Massive trade disruptions

Table 2 – *Continued from previous page*

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
Socio-economic Impacts						
On agriculture positive	No impact known or detectable	Biological traits and life-style suggest potential positive influence on the yield or quality, but not yet reported	Occasionally leading to additional yield or increased quality, yield or qual- ity increase small	Regularly leading to small yield or quality increase or occasionally to larger yield or quality increase	Regularly leading to larger yield or quality increase	Massive yield or quality gain caused by species
On animal production negative	No impact known or detectable	Occasional competition with, or loss of yield in livestock or animal production. Plant present but no operational obstruction or removal/control cost	Competition with, or loss of yield in livestock or animal production, transmission of diseases to livestock or production animals in the native area, but not yet reported from the area of introduction. Little operational obstruction or removal/control cost. Some trade disruptions	Competition more frequent with several livestock or production animal species, transmission of diseases reported, but infection rates low. Pollution by droppings on farmland which domestic stock are then reluctant to graze; for plants, loss of yield in livestock or production animals common, operational obstruction or removal/control cost minor. Plant may be toxic to livestock or production animals. Moderate trade disruptions	For animals, transmission of economically important diseases or hybridization with economically important game animals; for plants, loss of yield in livestock or production animals major, operational obstruction or removal/control cost considerable. Plant toxic to livestock or production animals, fatalities uncommon. Large trade disruptions	For animals, transmission of harmful diseases to or hybridization with livestock or production animals; for plants, loss of yield in livestock or production animals major, operational obstruction or removal/control costs are prohibitive. Plant highly toxic to livestock or production animals, fatalities reported. Massive trade disruptions
On animal production positive	No impact known or detectable	Biological traits and life-style suggest potential positive influence on animal production (e.g. direct: potential livestock or game species, fur production; indirect: e.g. fodder plant, (micro-) organisms increasing yield or quality of fodder plants), but not yet reported	Occasionally leading to increased production or quality, production increase small	Regularly leading to small production or quality increase or occasionally to larger production or quality increase	Regularly leading to larger production or quality increase	Massive production or quality gain caused by species
On forestry negative	No impact known or detectable	For animals, minor impact through herbivory; for plants, little or no loss of yield or quality or operational obstruction, no change to forest structure or regeneration	For animals, impact through herbivory, minor effect on forest growth, impact on seed dispersal; for plants, minor loss of yield or quality, or operational obstructions, minor changes to forest structure, minor reduction in regeneration. Some trade disruptions	For animals, constrains forest regeneration through browsing on young trees, damage to plantations, gnawing of bark, damage by causing floods; for plants, moderate loss of yield or quality, changes in forest structure, impeded regeneration. Moderate trade disruptions	For animals; moderate to strong damage to mature forest through seed consumption, bark stripping or antler rubbing, death of trees by felling or flooding. Killing trees by defoliating them for nesting material; for plants, strong loss of yield or quality, decline in desired canopy tree species, decline in regeneration potential, major changes to forest structure. Large trade disruptions	For animals; very strong damage to mature forest through seed consumption, bark stripping or antler rubbing, death of trees by felling or flooding; for plants, very strong loss of yield or quality, complete loss or replacement of desired canopy tree species, no regeneration, complete change in forest structure. Massive trade disruptions

Table 2 – *Continued from previous page*

Socio-economic Impacts

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
On forestry positive	No impact known or detectable	Biological traits and life-style suggest potential positive influence on forest production (e.g. direct: potential forestry species; indirect: e.g. (micro-) organisms increasing yield or quality of forestry plants), but not yet reported	Occasionally leading to increased forestry production or quality, compared to native species, production or quality increase small	Regularly leading to small forestry production or quality increase, compared to native species, or occasionally to larger production or quality increase	Regularly leading to larger forestry production or quality increase, compared to native species	Massive forestry production or quality gain, compared to native species, caused by species
On infrastructure negative	No impact known or detectable	Biological traits and life-style suggest potential damage to infrastructure (e.g. potential to increase soil erosion and decrease road stability, physical damage to property and infrastructure, disruption to transport and communications) but not yet reported	Occasional damage with minor economic losses, e.g. damage to fences, impact through pollution, accumulations of droppings, minor increases in soil erosion, localized damage to buildings and ground surfaces from roots and rhizomes (for plants), rare infrastructure problems (clogging up waterways, festooning power lines for plants)	Damage to fences and/or plantations, gnawing electricity cables etc., causing road accidents, nesting on current conductions. Moderate increase in soil erosion, moderate damage to property, buildings and infrastructure, frequent obstruction of waterways	Considerable damage to property and infrastructure, with considerable economic costs, damage through burrowing or nesting in buildings, or roots and rhizomes of plants. Major obstruction of waterways	Considerable damage to flood defence systems or other critical infrastructure, major soil erosion, danger to human safety, threat to transport safety
On infrastructure positive	No impact known or detectable	Have traits or attributes likely to help preserve infrastructure, but not yet reported	Minor ability to preserve and enhance infrastructure, but performance no better than native or non-plant alternatives. No economic gain	Moderate ability to preserve and enhance infrastructure (prevent soil erosion), better than non-plant alternative. Marginal economic gain	Strong ability to preserve and enhance infrastructure better than nonplant alternative, e.g. flood defence and soil preservation, prevention of landslides. Moderate economic gain	Best option for preserving and enhancing infrastructure, better than non-plant alternative, high economic gain, preserves human safety
On human health negative	No impact known or detectable	Host of one or more harmless diseases with the possibility of infecting humans, not yet reported; for plants, known to be mildly toxic, causing mild discomfort, no cases yet reported	Host of several harmless diseases, indirect transmission or possibility of direct transmission, but only a small percentage of the human population at risk, health hazard from soil and water contamination caused by droppings; for plants, mildly toxic or causing mild discomfort, exposure risk low (not easily ingested, not airborne, direct contact causes no reaction), few cases reported	Direct infection with one or more harmless diseases, occasional health threat through bites or other attacks; for plants, toxic, and/or causing pain, injury or discomfort, exposure risk moderate (poisoning through ingestion, airborne, direct contact causes reaction), moderate number of cases reported	Direct transmission of several diseases, infection by contaminated food common, host of harmful diseases in the native range, but not yet known from the invaded range. Health threat through bites or other injuries happen more often, rarely fatal. Plants highly toxic, and/or causing strong pain/discomfort, but rarely fatal - many cases reported. Exposure risk high, through ingestion, contamination, direct contact, airborne	Vector of harmful diseases to humans and/or many diseases frequently transmitted. Health threat through bites or other injuries happen frequently, more often fatal. Plants highly toxic, causing severe pain and/or discomfort, fatalities reported, or severe disruption to daily life caused through effects on human health. High risk of exposure

Table 2 – *Continued from previous page*

	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5
On human health positive	No impact known or detectable	Biological traits and life-style suggest potential positive effect on human health (direct: e.g. potential medicinal species; indirect: e.g. antagonist of a health threat, ameliorating human living conditions), but not yet reported	Occasional, small positive effect on human health	Regularly small positive effect on human health, or occasional, larger positive effect on human health	Regularly leading to larger positive effect on human health	Massive positive effect on human health caused by species
On human social life negative	No impact known or detectable	Biological traits and life-style suggest potential for disturbance in recreational or residence areas (e.g. by noise, pollution, overgrowing), but nothing yet reported	Occasional small disturbance, only small percentage of human population affected	Regular small disturbance, or occasional larger disturbance	Regular larger disturbance. Recreational value of a habitat or a landscape strongly affected	Massive disturbance; complete loss of recreational value of a habitat or a landscape
On human social life positive	No impact known or detectable	Biological traits and life-style suggest potential positive effect for recreational or residence areas (e.g. charismatic or decorative species, species ameliorating the environment by providing e.g. shade, or having edible parts, or species potentially used for angling or hunting), but not reported so far	Occasional small positive effect for recreational or residence areas, only small percentage of human population affected	Regular small positive effect for recreational or residence areas, or occasional larger positive effect for recreational or residence areas	Regular larger positive effect for recreational or residence areas. Recreational value of a habitat or a landscape strongly increased	Massive positive effect for recreational or residence areas. Massive gain of recreational value of a habitat or a landscape

Table title: Socio-economic Impacts

Assessing a confidence score

For each alien taxon that is assessed and for which adequate data exist to allow for classification, the assessor should place it in the most likely of the five impact categories (Score 0, 1, 2, 3, 4 or 5) and assign a level of confidence to this placement according to the availability and reliability of evidence, the type of data used to make the assessment, the spatial scale over which data were recorded, and whether or not the evidence is contradictory.

Confidence is categorized into five levels:

- **Very confident** (80-100%) should be assigned when there is relevant direct observational evidence to support the assessment; the data are reliable and of good quality; impacts are recorded at the typical spatial scale at which original native communities can be characterized; and all evidence points in the same direction.

- **Somewhat confident** (60-80%) should be assigned when there is relevant direct observational evidence to support the assessment and all evidence points in the same direction, but some of the data are inferred (e.g. impact estimated from mathematical models); impacts are recorded at a spatial scale which may not be relevant to the scale over which original native communities can be characterized but extrapolation or downscaling of the data to relevant scales is considered reliable, or to embrace little uncertainty.

- **Medium confidence** (40-60%) should be assigned when there is some direct observational evidence to support the assessment, but some of the data are inferred (e.g. impact estimated from mathematical models); impacts are recorded at a spatial scale which may not be relevant to the scale over which original native communities can be characterized but extrapolation or downscaling of the data to relevant scales is considered reliable, or to embrace little uncertainty; and/or there is some degree of ambiguity in the direction or magnitude of the impact.

- **Somewhat not confident** (20-40%) is defined as no direct observational evidence to support the assessment, for example only data from other species have been used as supporting evidence; or data are of low quality or strongly ambiguous; or impacts are recorded at a spatial scale which is unlikely to be relevant to the scale at which original native communities can be characterized and extrapolation or downscaling of the data to relevant scales is considered unreliable or to embrace significant uncertainties.

Assessing the reliability of the data

Nentwig et *al.* 2010 and Kumschick et *al.* 2012 suggested including information about the reliability of the data source used for scoring:

- **Low**: mentioned in paper, no reference, speculation, expert judgment

- **Medium**: evidence in literature, observational

- **High**: demonstrated evidence in peer-reviewed literature, experimental.

This also deals with the fact that an impact score of 0 can be both, "no impact known" and "no impact detectable". Including a certainty level enables to distinguish these possibilities (e.g. Low: no information. High: demonstrated evidence in peer-reviewed literature, experimental). These certainty levels and data reliability are to be communicated to the decision maker and can potentially influence the final decision making. Furthermore, they can identify research needs (e.g., species with large effects with low certainty).

References

[1] Kumschick, Sabrina and Bacher, Sven and Dawson, Wayne and Heikkilä, Jaakko and Sendek, Agniezska and Pluess, Therese and Robinson, Tammy and Kühn, Ingolf (2012). A conceptual framework for prioritization of invasive alien species for management according to their impact, *NeoBiota*, 15(69).

[2] Nentwig, Wolfgang and Kühnel, Elfi and Bacher, Sven (2010). A Generic Impact-Scoring System Applied to Alien Mammals in Europe, *Conservation Biology*, 24(1):302–311.