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Guidelines for the Generic Ecological Impact Assessment of Alien Species

Version 3.3

Contents

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1. Background

1.1. Alien species

The spread of alien species as a result of human activity is a global problem with massive ecological consequences (Kumschick et al. 2015), leading to a homogenisation of nature (Dar and Reshi 2014). On a global basis, alien species are listed among the greatest threats against biodiversity (Lockwood et al. 2013). In IUCN's global Red List, invasive alien species are identified as a threat to 35% of threatened birds, 29% of the threatened amphibians, and 17% of the threatened mammals (IUCN 2015). In Norway, alien species are listed as a threat to relatively few species (2%; Henriksen and Hilmo 2015).

It has been estimated that, on a global basis, roughly 10% of newly introduced alien species will be able to get established, and that 10% of these will turn into problem species (Williamson 1996). These figures vary a lot both geographically and between different groups of organisms, and the validity of this 'rule' is contested (Lockwood et al. 2005). For Nordic environments, it has been estimated that 3–5% of introduced vascular plants become invasive (Fremstad et al. 2005). Repeated introductions increase the establishment probability (Blackburn et al. 2009), and the size of the introduced population has a similar effect. On the other hand, there are examples of one fertilised female founding well-established and highly expansive populations (Zayed et al. 2007). Whether an alien species is able to establish in a new area, depends among other things on its demographic and physiological characteristics (e.g., ability to utilise pioneer habitats, short generation time, high tolerance for environmental stochasticity, generalistic and opportunistic diet) as well as the availability of fitting habitats.

The climate in Norway is characterised by short vegetation periods and long, cold winters. This may be a partial explanation for the fact that alien species are a limited problem. However, a milder climate may provide better conditions for a number of alien species in the future (Fremstad et al. 2005, Iacarella et al. 2015, Dullinger et al. 2017), increasing their likelihood to survive, establish and spread.

Alien species that establish in a new area may have considerable ecological effects locally, either by acting as a novel decomposer, herbivore, predator or parasite in ecosystems, but also by disrupting trophic interactions when constituting a novel resource. When filling the niche of a native species (spatially and/or trophically), or when having traits that negatively affect the viability of other species (e.g., through toxicity or transmission of infectious diseases), the population dynamics of native species can be changed, ultimately resulting in displacement (Williamson 1996). Alien species may bring about changes in the condition and state of nature types, and thus modify and threaten the occurrence and diversity of nature types, too (Lindgaard and Henriksen 2011). Finally, some alien species have the ability to transfer genetic material to other species (introgression). Such genetic contamination may affect the genetic constitution of native species, and thereby change their characteristics, their ecological and their evolutionary potential.

1.2. Ecological risk assessments of alien species in Norway

By ratifying the Convention on Biological Diversity (CBD 1992), Norway has committed itself to, as far as it is possible and practical, preventing the introduction of alien species, as well as controlling and eradicating alien species that may threaten ecosystems, habitats or species. Increased measures against harmful alien organisms are furthermore required by by law (naturmangfoldloven 2009, ballastvannforskriften 2009, forskrift om utsetting av utenlandske treslag 2012, forskrift om fremmede organismer 2015).

The Norwegian Biodiversity Information Centre published the first Norwegian Black List in 2007 (Gederaas et al. 2007). This list only contained a selection of alien species in Norway, assessed using qualitative criteria. An updated list of all known alien species in Norway (within defined delimitations) was published in 2012 (Gederaas et al. 2012). This second risk assessment was based on a newly developed, semi-quantitative set of criteria (Sandvik et al. 2013).

The third survey of alien species and of the ecological risks they pose, is scheduled for publication in 2018. The risk assessments underlying this list will be carried out during 2017. This current (third) round of assessments was preceded by a broad evaluation of the needs and a revision of the methodology: a scientific reference group was established in 2015, which gave important feedback on definitions, delimitations and criteria. A preliminary version of the guidelines was circulated in spring 2016 in order to encourage input from a variety of institutions and user groups. The Norwegian Biodiversity Information Centre had several meetings with key user for further calibration. The process also involved a cooperation with the Norwegian Scientific Committee for Food Safety (VKM) in order to ensure a uniform presentation of the assessments made by VKM and the Norwegian Biodiversity Information Centre. Finally, Swedish authorities have started a cooperation with the Norwegian Biodiversity Information Centre, and are currently preparing a risk assessment based on the same method.

The method that is used in 2017 is called *Generic Ecological Impact Assessment of Alien Species* (GEIAA). The set of criteria underlying this method is part of these guidelines (Appendix I). It is a revised version of the set of criteria that was used in 2012 (the changes are summarised in chapter 6). Criteria A–I carry the same meaning as in 2012, but some of them have been modified or calibrated (details on the reasons are provided in Appendix II). Due to this revision, the current set of criteria is quantitative throughout (cf. Appendix III).

The criteria are used to quantify and describe the risk that alien species establish or expand in Norway, and that they exert negative ecological effects on the native biodiversity. Non-ecological effects of alien species are not assessed by the Norwegian Biodiversity Information Centre, but are mentioned in the species description.

The current process will result in an updated list of alien species in Norway, including a Black List. The list will be published in 2018 as an online-only publication.

The main aim of the list is to facilitate knowledge-based management of biodiversity, but also to spread information about alien species in Norway to the general public and other relevant target groups in society. It is important to mention that it is not the responsibility of the Norwegian Biodiversity Information Centre to decide on or carry out measures against any species. This is the responsibility of the relevant management authorities. An assessment of the ecological risks posed by alien species is a crucial first step towards a prioritisation of management efforts, but it is not necessarily sufficient for deciding such priorities (which may have to take into account other aspects, such as economy, human health or cultural heritage).

The Norwegian Biodiversity Information Centre has established several expert groups. Each of the expert groups is responsible for risk-assessing the alien species (including door knockers and regionally alien species) within a certain taxon.

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1.3. AlienSpeciesDatabase

As a platform for carrying out the assessments of ecological risk posed by alien species, the Norwegian Biodiversity Information Centre has designed a purpose-made web application: the AlienSpeciesDatabase. This application has two interfaces: an assessment interface and a public interface. The assessments and all documentation have to be registered in the assessment interface, which is only accessible to the expert groups. This user-friendly interface facilitates standardisation across expert groups and provides a safe way of archiving all data. In addition, it ensures that the most current version of all assessments is always available to all experts involved, and allows a close follow-up of expert groups by the Norwegian Biodiversity Information Centre. The AlienSpeciesDatabase also contains useful links and tools, which simplify a number of tasks, such as the estimation of areas of occupancy and of extents or occurrence. Information from the 2012 risk assessment has, as far as possible, been transferred to the AlienSpeciesDatabase. It is important that the experts check this information for continued validity, and update it where the situation or the state of knowledge has changed since 2012. After all assessments are completed and quality-assured, the data will be published using the public interface of the AlienSpeciesDatabase.

Login and structure

The URL of the AlienSpeciesDatabase is https://database.artsdatabanken.no/FAB3 (for the assessment interface). Unfortunately, full functionality can only be guaranteed when using Google Chrome.

When logging in for the first time, a user account has to be created and approved by the Norwegian Biodiversity Information Centre. User name and password can be chosen by the user. Use the 'forgotten password' button to receive an e-mail reminder of the password.

A list of alien species (including door knockers) is available in the AlienSpeciesDatabase. The list can be extended at any time by giving feedback to the Norwegian Biodiversity Information Centre (postmottak@artsdatabanken.no).

Before a species can be described and assessed, it must be 'locked' in the species list. Species that are not locked (or that are locked by other users) may be read, but cannot be edited. The expert group leader has to approve all assessments that are finished, using an 'approval' button in the species list.

The AlienSpeciesDatabase is structured using the following tabs and subtabs:

- Species information (see chapter 3. of the guidelines)
  - Species status (see section 3.1. of the guidelines)
  - Species characteristics (see section 3.2. of the guidelines)
  - Entry (see section 3.3. of the guidelines)
  - Pathways (see section 3.4. of the guidelines)
  - Distribution history (see section 3.5. of the guidelines)
- Nature types (see chapter 4. of the guidelines)
- Risk assessment (see chapter 5. of the guidelines)
  - Invasion potential (see section 5.1. of the guidelines)
  - Ecological effect (see section 5.2. of the guidelines)
  - Geographical variation (see section 5.3. of the guidelines)
  - Climate effects (see section 5.4. of the guidelines)
  - Documentation (see section 5.5. of the guidelines)
- References (registering and editing references)

The menu list at the top has the buttons 'Information', 'Choose species', 'Save' and 'Logout':

- 'Information' contains links to the guidelines and the AlienSpeciesDatabase 2012 (Norwegian).
- Changes have to be saved before choosing a new species and leaving the application.

1.4. Verifiability as a general requirement

All species assessments must be verifiable and testable. It is, therefore, a basic requirement that information input to the AlienSpeciesDatabase is documented and referenced. This is especially important for all information that underlies the scores and impact categories.

A criterion is thus not regarded as met unless documentation is available. This documentation may consist of scientific (peer-reviewed) articles or reports (in which case it is sufficient to quote these sources), but also of own observations and other unpublished data (as long as these are made available). It is a requirement that unpublished datasets are uploaded to the AlienSpeciesDatabase, at least when they contain essential information for verification of the assessment. Personal communications from other experts needs to be documented with name, date and institution. Such sources can be provided in text boxes. Quoted references have to be uploaded on the tab called 'References'.

Documentation should include a clear description of the assessment methods the expert has used (including the assumptions which the assessment is based upon). Quantitative assessments pose higher demands to documentation than qualitative ones. The assessment of a given criterion may consist of a specific, numerical and referenced estimate. However, it may also consist of an expert judgement. Expert judgements do not conflict with a quantitative method *as long as they are documented and based on the threshold values* specified in the set of criteria (cf. Appendix III). In such cases, documentation consists of substantiating that the value lies between two specific thresholds, without the to provide a numerical estimate. The experts are encouraged to exercise discretion and draw on their personal expertise. Documentation may consist of own observations or own analyses of the relevant situation for a species, but only when these are written out in the appropriate text boxes of, or uploaded to, the AlienSpeciesDatabase.

For some species, there will be no documentation available on the invasion potential or on ecological effects in Norway. This is the case for many door knockers, but even some alien species that are already present in Norway – either because they are so new, hard to find, or simply poorly investigated. If there are insufficient data from Norway, documentation may consist of:

- data on the same species from countries that are bioclimatically comparable to Norway,
- data on the same species from countries that are bioclimatically different from Norway,
- data on a closely related species with a comparable lifestyle and demography.

This list is in approximately prioritised order. There may be cases, however, were Norwegian data on a close relative give a better indication of the characteristics of the species than data from the area of origin of the species. Such decisions have to be based on the experts' judgement and to be described in the documentation.

Uploading datasets

On relevant tabs in the AlienSpeciesDatabase, there are buttons for uploading datasets (distribution history / 3.5., lifetime / 5.1.1., expansion speed / 5.1.2.). These should be used to upload data that are used or that are of relevance for the risk assessment. Own observations and unpublished data have to be uploaded, where these are the only documentation on which the assessment is based, or where they contain relevant data for the assessment.

Accepted file formats are spread sheets (OpenOffice, Excel), plain text (txt, csv), formatted text (OpenOffice, Word, rtf) or pdf. The datasets will not be published in the AlienSpeciesDatabase or elsewhere, but will be archived together with the risk assessments. Upon request, single datasets may be made available for single users.

1.5. Relevant background data

Auxiliary information that is relevant for risk assessments of alien species in Norway and helps ensuring a common knowledge base, will be available from the webpages of the Norwegian Biodiversity Information Centre (http://www.artsdatabanken.no/fremmedearter). This includes information about area use, climate projections and changes in Norwegian nature:

- Species Map Service (http://artskart.artsdatabanken.no)
- Interactive climate projections (http://www.klimaservicesenter.no)
- Climate in Norway 2100 (Hanssen-Bauer et al. 2015) [pdf]
- Nature in Norway, version 2 (Halvorsen et al. 2015; partly version 1, Halvorsen et al. 2009)
- Norwegian Red List for Species 2015 (Henriksen and Hilmo 2015) [link]
- Norwegian Red List for Ecosystems and Habitat Types 2011 (Lindgaard and Henriksen 2011) [link]
- Results of the countrywide forest valuation (Granhus et al. 2012 [pdf], Storaunet and Rolstad 2015 [pdf], and http://www.skogoglandskap.no/kart/skogressurskart)

1.6. Acknowledgements

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2. Definitions and delimitations

2.1. Alien species

The general definition of alien species applied in Norway follows IUCN (2000:4–5):

> ***Alien species* means a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce.**

The term 'alien species' (*fremmed art*) is now well established in Norway, and is preferred over expressions such as 'non-native species', 'exotic species' or 'invasive species', which are potentially misleading. The term 'invasive' can be understood to suggest a large potential to invade (i.e. to spread); however, not all alien species are invasive in this sense, and there are native invasive species, too.

That a species occurs outside of its natural range and dispersal potential means that its alien population has been *introduced* anthropogenically (or originates from a population that has been so introduced). The terms 'introduced' and 'introduction' are here used in a broad and neutral sense that does not imply intent:

> ***Introduction* refers to any human activity which has the intended or unintended consequence that individual(s) of an alien species arrive in Norwegian nature.**

'Norwegian nature' is defined below (section 2.3.). Introduction of alien species thus includes the following pathways (cf. Appendix IV):

1) intentional release;
2) escape from confinement (such as breeding, cultivation, farming etc.);
3) contaminants (incl. parasites) introduced during transport of animals, plants or organic materials;
4) stowaways introduced during transport of people, equipment, bulk, vehicles or boats;
5) spread through man-made corridors;
6) secondary spread, i.e. unaided dispersal from areas where presence is due to pathways 1–6.

If it is uncertain whether a species has arrived in Norway unaidedly or by any of the above anthropogenic pathways (and, therefore, whether it is to be regarded as *alien to Norway*), the decision depends on the most likely alternative: if the alternative possibility is that the species is native, the more likely of the two scenarios is to be assumed. (This is in order to avoid that species end up both on the Red List and the Black List.) If, on the other hand, the alternative possibility is that the species is an irregular visitor (vagrant), it should be risk-assessed as alien when there is any reasonable doubt about the status.

2.2. Native species

Effects on native species are a central factor in risk assessments of alien species. It is therefore important to point out that the term 'native species' is here understood as comprising all species that are considered for Red-Listing (i.e., all species that are placed or can be placed in the Red List categories DD, LC, NT, VU, EN or CR; Henriksen and Hilmo 2015). This entails:

> ***Native species* are species that occur in Norway and that (a) have been stably reproducing in Norway by 1800; *or* that (b) have a stably reproducing population in Norway that did not originate in introduced individuals; *or* that (c) are migrants in Norway.**
>
> ***Threatened species* are native species that are placed in the Red List categories VU (vulnerable), EN (endangered) or CR (critically endangered) according to the *Norwegian Red List for species 2015* (Henriksen and Hilmo 2015).**

Here, 'stably reproducing' entails that more than 20 individuals have reproduced unaidedly for more than 10 years; 'introduced' is used in accordance with section 2.1.; and 'migrant' is understood as a species that regularly visits Norwegian territories with an abundance that exceeds 2% of the species's global population (cf. Artsdatabanken 2014:7).

NB! *Native species, as the term is used here, is* not *an antonym (or opposite) of alien species.* There are species in Norway that are *both* alien *and* native (the intersection between the two large ellipses in Figure 1), and some species that are *neither* alien *nor* native (vagrants). The various combinations are illustrated in Figure 1.

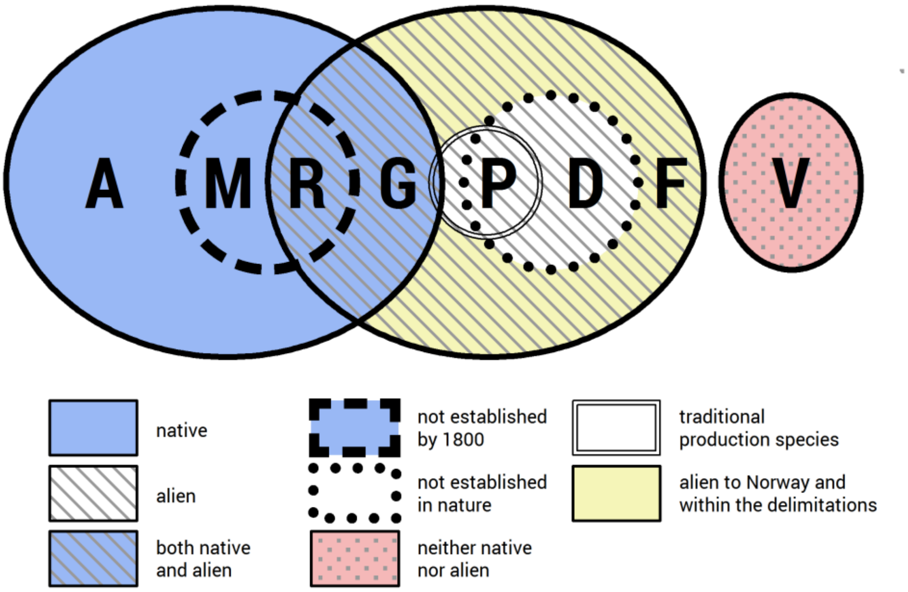

Figure 1: Alien and native species. The scheme shows all groups of species that can occur in Norway. According to the definitions adopted in these guidelines (cf. section 2.1. and 2.2.), there are some species that are *both* alien and native, as well as species that are *neither* alien nor native. *All* species in **F** and *some* in **R** and **D** are risk-assessed.

A *Originally* native species (*autochthonous* or *indigenous* species).
M *Migrants* (not established) and newly immigrated species (established after 1800) that are not introduced.
R *Regionally* alien species (native in *Norway*, but introduced to other parts of the country; see 2.6.2.).
G 'Old' introduced species that have established stably reproducing populations before 1800.
P *Production species* that have been in large-scale use by 1700.
D *Door knockers* (alien species that are not established in Norway, but may in the future; see section 2.5.).
F Species that are introduced to, and established in, Norway, but establishment happened after 1800.
V Irregular visitors (*vagrants*).

2.3. Norwegian nature

The 'assessment area' for an alien species is here referred to as *Norwegian nature* and defined as follows:

> ***Norwegian nature* encompasses any part of Norway that is outdoors (including heavily modified nature) and the native species occurring there; for production species, their production area does not count as Norwegian nature.**
>
> **A *production species* is a species that is used in production of goods or services. Production species are regarded as *traditional* if they have been in large-scale use in Norway prior to 1700.**
>
> **The *production area* of a given production species is the confined area of heavily modified nature that is specifically allocated to the production of this species.**

NB! *It follows from this definition that the extent of production area is always* specific to a particular production species*, and, consequently, that the extent of Norwegian nature is species-specific, too.*

'Production' is to be understood in a wide sense, including not only production of food, timber and other animal and plant products, but also for instance recreation. Examples of production species and areas are thus vegetables on a field; trees in a plantation; farm animals on a pasture; fresh- or saltwater fish in fish farms; garden plants or pet animals in a private garden; water plants or fish in a garden pond. The delimitation of production areas will often, but not always, be sharp (e.g., fences). A buffer zone as wide as the individuals are high should be included into the production area at its fringes.

The subdivision of Norwegian nature and the definition of heavily modified nature are covered by the 'NiN system' (*Nature in Norway*, Halvorsen et al. 2015) and briefly explained in Appendix V. Please note that the term *Norwegian nature* as such is not based on NiN, but is needed here in order to define the assessment area for the risk assessments.

2.4. Establishment

Establishment is a key term when it comes to alien species. The definition used here is rather wide, in that it merely requires reproducing individuals rather than a population of a certain size:

> **A species is regarded as established in Norway if and only if it is reproducing unaidedly outdoors, i.e. when viable offspring is produced outdoors and without human management.**

Offspring may be produced sexually or asexually. The observation of mature individuals *that have been introduced themselves* ('first generation' individuals after introduction) are *not* regarded as documentation of establishment. *Neither* are individuals that most likely have been produced indoors *or* under human management (e.g., livestock; for delimitations, see IUCN 2016:8).

NB! *It follows from this definition that a species may be established before it is introduced.* For example, if a tree species reproduces (without direct management) on the species's own plantation, it will be regarded as established in *Norway*. However, because the reproduction did not happen in *Norwegian nature*, the species is not regarded as introduced (according to the definitions provided in sections 2.1. and 2.3.). The rationale is that a species is very likely to be able to reproduce outside its production area (i.e., in Norwegian nature) when it is known to reproduce unaidedly outdoors.

2.5. Door knockers

Species that might become established in the future, are referred to as 'door knockers':

> **A *door knocker* is an alien species that is not currently established in Norway, but that can be expected to become established in Norway in within 50 years.**

Door knockers can roughly be divided in three groups of species:
- alien species that are already present in Norway, but that do not currently reproduce, or that currently only reproduce indoors or under management (e.g., garden plants, aquarium fish, species that live in residential buildings, greenhouses, barns, storerooms and the like) – this group may establish when the climate or environment change, allowing the species to reproduce unaidedly outdoors;
- alien species that are already present in neighbour countries and may reach Norway without further anthropogenic assistance, i.e. by unaided spread or through corridors (see Appendix IV);
- alien species that are absent from Norway, but that may reach Norway by means of existing and relevant pathways (intentional or unintentional import or transport, see Appendix IV) from an area that has similar bioclimatic conditions to the destination.

Relevant authorities have requested risk assessments of some door knockers (see Appendix VIII). The risk assessors are asked to decide whether further species deserve being risk-assessed as door knockers. The selection of species considered as door knockers can be adjusted throughout the assessment period. (See section 1.3. on how to include new names into the database.)

NB! *Door knockers are risk-assessed based on data from abroad, extrapolating these results, as far as possible, to Norwegian conditions (i.e., correcting for differences between the other country and Norway).*

2.6. Delimitations

Section 2.1. provides the general definition of alien species. However, not all species that meet this definition are included in the risk assessments. The subset of alien species that *are* to be risk-assessed is specified using the following four *delimitations* in time and space, ecology and taxonomy.

2.6.1. Historical delimitation

According to the general definition, species introduced in the Upper Palaeolithic are regarded as alien. However, knowledge about the native flora and fauna in Norway before c. 1800 is rather incomplete. Using a too early demarcation line would therefore introduce a great deal of uncertainty about the nativeness of species. For this reason, and fully acknowledging the arbitrariness of this date, the year 1800 is here treated as the historical delimitation for risk assessment. To avoid conflicts between the Red List and the Black List, the same delimitation is used as an inclusion criterion in the Norwegian Red List.

> **An alien species is *not* to be risk-assessed if it was established with a stably reproducing population in Norway by the year 1800.**

In accordance with the definition in section 2.2., a species must have reproduced unaidedly for a period of more than 10 consecutive years, in order to be regarded as 'stably reproducing'. If this period *began* in 1790 or earlier (so that the species had been reproducing for 11 years in 1800 or earlier), the species is regarded as native and is not risk-assessed.

This has the following implications:

1) Species that have been introduced to Norway *after* 1800 and did not previously have stably reproducing populations in Norway, *are* to be risk-assessed.
2) Species that have been introduced to Norway before 1800 *and* had established stably reproducing populations before 1800, are in this context treated as native and are *not* to be risk-assessed.
3) Species that have been introduced to Norway before 1800, but had *not* established stably reproducing populations before 1800, *are* to be risk-assessed.
4) Species that have previously been native to Norway, but went *extinct after 1800*, are still regarded as native, even if they are re-introduced, and are therefore *not* to be risk-assessed.
5) Species that have previously been native to Norway, but went *extinct before 1800*, are not regarded as native any more and *are* therefore to be risk-assessed, if they are re-introduced.

If species that have been *introduced* before 1800 are risk-assessed, this needs to be justified. If the time of *establishment* is uncertain, the species should be risk-assessed if it is more likely that the species was established after than before 1800. In both cases, an explanation should be provided in the documentation.

2.6.2. Geographical delimitation

The general definition of alien species applies to all occurrences outside the species's natural range and dispersal potential, but does not specify any minimum distance. For the purpose of risk assessment, the following delimitation is applied:

> **An alien species *is* to be risk-assessed as alien only if it has (or had) to cross national borders or the boundaries of the Norwegian Economic Zone during its introduction. Other species *may* be risk-assessed as regionally alien species.**

A species that is native to Norway and has been introduced to novel areas within Norway due to human activity, is thus not regarded as alien to Norway (although it may be assessed as a *regionally alien* species, see below). A species that is native to mainland Norway but introduced to Norwegian islands in the Arctic (Svalbard or Jan Mayen), is considered alien to these islands – and vice versa.

Norway's national borders are its borders towards Sweden, Finland and Russia plus the outer boundaries of the Norwegian waters as specified below. If species have entered Norway from Sweden and/or Finland (through secondary spread), they are regarded as alien to Sweden and Finland following the same definitions and delimitations as for Norway. Species that have entered Norway from Russia may be regarded as alien even if they have been spread internally within Russia, viz. if the displacement was over huge geographical distances and/or across biogeographical regions.

The risk assessments cover Norwegian areas on the Northern Hemisphere, i.e.:

- the Norwegian mainland (consisting of the mainland itself and nearby islands; c. 324 000 km^2);
- Svalbard (Spitsbergen and surrounding islands, including Bjørnøya and Hopen, as defined under the Svalbard Treaty of 9th February 1920; c. 61 000 km^2);
- Jan Mayen (377 km^2);
- maritime waters around mainland Norway, consisting of Norwegian territorial waters (within 12 nautical miles) and the Norwegian Economic Zone (within 200 nautical miles, as defined under legislation of 17th December 1976; c. 933 000 km^2 in total);
- the Fishery Protection Zone including territorial waters around Svalbard (within 200 nautical miles, as defined under legislation of 15th June 1977; c. 806 000 km^2);
- the Fishery Zone including territorial waters around Jan Mayen (within 200 nautical miles, as defined under legislation of 23rd May 1980; c. 293 000 km^2).

Regionally alien species

The risk assessment covers species that are alien *to Norway*. In addition, the possibility exists to risk-assess selected *regionally alien* species.

> **Regionally alien species are species that are native to Norway, but that have been introduced to novel areas within Norway after 1800. Occurrences in the species's natural range (extent of occurrence, past or present) are referred to as *regionally native*; occurrences outside these species' natural range and dispersal potential are referred to as *regionally alien*.**

The terms *autochthonous* and *allochthonous* can be used synonymously with regionally native and regionally alien, respectively. Native species spread anthropogenically to novel areas within Norway are always to be referred to as *regionally alien* species. If the term *alien species* is used without the qualifier 'regional', it is meant to refer to species that are *alien to Norway* as a whole.

Regionally alien species are only risk-assessed in selected cases. Relevant authorities have requested risk assessments of some regionally alien species (see Appendix VIII). The risk assessors are asked to decide whether further species deserve being risk-assessed as regionally alien.

The risk assessment of a regionally alien species is restricted to the Norwegian areas that do not hold regionally native occurrences of the species. The sub-populations assessed may originate from:

- individuals from Norwegian sub-populations that have been introduced to novel areas; or
- individuals that have been introduced to Norway from abroad, but that belong to a species that occurs natively in Norway.

As outlined above, species that are spread from mainland Norway to the Norwegian islands in the Arctic (or vice versa) are regarded as alien, not as regionally alien.

2.6.3. Ecological delimitation

The following ecological delimitations apply:

> **Alien species *are* to be risk-assessed if they are (or have been) established in Norway. Alien species that are not established, *should* be risk-assessed if they have the potential to establish in Norway within 50 years, but, if needed, *may* be risk-assessed even without such a potential. Traditional production species are *not* to be risk-assessed.**
>
> **Risk assessments are *only* to include negative ecological impacts on Norwegian nature.**

Please note that production area is species-specific (cf. section 2.3.). Alien production species that occur on the production area of *another* (native or alien) species, have thus entered Norwegian nature and are to be risk-assessed. The following rules apply for production species:

- When estimating invasion potential of production species, their own production area is *disregarded*.
- Ecological effects of production species on their own production area are *disregarded*.
- Ecological effects of production species outside their production area, on the other hand, *are* to be considered during risk assessment. Such effects include
  - *distance effects* (effects that have a spatial scale exceeding the production area, even if the species does not leave this area; examples are genetic contamination by means of wind-spread pollen, or population declines in visiting pollinators caused by toxic nectar);
  - effects of *escaped individuals* outside their production area (even without establishment);
  - occurrences and effects of *established populations* outside the production area.

Alien species that are excluded by the ecological delimitation for all their occurrences, are still to be risk-assessed *as door knockers* (see section 2.5.) if they have the potential to establish within a 50-year time-frame, or if they have ecological effects (via distance effects or escaped individuals).

2.6.4. Taxonomic delimitation

The definition of alien 'species' does not distinguish between taxa on the species level and taxa at lower taxonomic levels. This necessitates the following delimitation:

Alien taxa *are* to be risk-assessed if they are ranked as a species.
Alien taxa below the species level *may* be risk-assessed if needed.

Taxa below the species level include subspecies, varieties, cultivars, hybrids and other categories. Genetically modified organisms (GMO) are *not* included in this risk assessment (as these are assessed by the Norwegian Scientific Committee for Food Safety, VKM). Alien taxa below the species level are risk-assessed using the same guidelines as alien species, with the only exception that criterion H is somewhat modified (see last paragraph of section 5.2.4.).

No specific species concept is adopted for the risk assessment. In order to decide whether a taxon constitutes a species, one should simply follow the accepted taxonomic practice for the group concerned. While the species level, at least according to some species concepts, is a naturally given and thus potentially objective level in the taxonomic hierarchy (Ghiselin 1997, Hull 1997), the same does not apply to categories below the species level (cf. Sandvik 2001). The risk assessment aims at producing an exhaustive list of (multicellular) alien *species*. The same goal does not exist for alien taxa *below the species level*, where an exhaustive list is impossible in principle.

Relevant authorities have requested risk assessments of some taxa below the species level (see Appendix VIII). Risk assessors are free to assess further taxa when the available information and the difference from the 'parent species' (the species to which the taxon belongs) are sufficient for separate assessments. This applies irrespective of whether the 'parent species' itself is native. Therefore, two situations have to be distinguished:

- Non-assessed alien taxa below the species level belonging to a species that is *not* native in Norway, are automatically assumed to share the impact category of their 'parent species'.
- Non-assessed alien taxa below the species level belonging to a species that *is* native in Norway, are simply treated as 'not assessed' (or 'outside the delimitations').

Unicellular organisms are not risk-assessed in their entirety. However, some selected unicellular species may get risk-assessed.

2.6.5. Summary and examples

For a taxon to be risk-assessed,

- it has to be alien according to IUCN's definition (section 2.1.),
- it has to be established in Norway (section 2.6.3.),
- it must not have been stably reproducing in Norwegian nature prior to 1800 (section 2.6.1.),
- it must have crossed a national border (or be introduced to/from Svalbard; section 2.6.2.), *and*
- it has to be a taxon on the species level (section 2.6.4.).

In addition, a taxon *may* be risk-assessed (based on needs and/or requests by relevant authorities, cf. Appendix VIII) if it:

1) may establish in Norway within 50 years (door knocker) or have effects without establishment;
2) is a taxon below the species level that is sufficiently different from its 'parent species'; *or*
3) is a native species that has been introduced to novel areas in Norway (regionally alien species).

The definitions and delimitations are here illustrated with some examples:

- *Leucanthemum vulgare* [oxeye daisy] has most likely been introduced anthropogenically to Norway with agriculture. Since this has happened long before 1800, the species is not to be risk-assessed. (It is treated as native for the purposes of this risk assessment.)

- *Streptopelia decaocto* [Eurasian collared dove] has not been established in Norway prior to 1800, but arrived during the 20th century. Because it has immigrated unaidedly, however, it is a native species and is *not* to be risk-assessed.
- *Ovibos moschatus* [muskox] is regarded as alien to Norway. It is 30 000–100 000 years ago that *O. moschatus* was part of the Norwegian fauna, and the current population was introduced anthropogenically during the 20th century. It is therefore to be risk-assessed.
- *Perdix perdix* [grey partridge] is extinct as a breeding bird in Norway. Nevertheless, it is treated as native to Norway, because its original establishment happened without human involvement, and it went extinct later than 1800. The species is therefore still regarded as native and is *not* to be risk-assessed if it should be introduced.
- *Acer pseudoplatanus* [sycamore] has, as far as is known, been introduced to Norway for the first time around 1750. The first reports of escaped occurrences seem to be from the 1890's, however. In this case, the species was *introduced before 1800*, but *established itself with a stably reproducing population only after 1800*, and is thus to be risk-assessed as an alien species.
- *Sus scrofa* [wild boar] has had a native population in Norway some thousand years ago. It is to be risk-assessed as alien to Norway, even though it immigrated unaidedly from Sweden. The reason is that the species was *absent from Norway and Sweden in the year 1800*, and that it is thus alien to Sweden according to the delimitations used in Norway (irrespective of the fact that Swedish regulations define *Sus scrofa* as native to Sweden).
- *Paralithodes camtschaticus* [red king crab] has not been released in Norway, but has spread unaidedly from the Russian to the Norwegian part of the Barents Sea. However, because the Russian source population has been released anthropogenically, the species is regarded as alien to Norway. While the species is not alien to Russia (it occurs naturally at the Kamchatka Peninsula), an intended transport over more than 5000 km, from the Pacific Ocean to the Barents Sea, is a clear instance of anthropogenic introduction. The species is therefore to be risk-assessed.
- *Balaenoptera musculus* [blue whale] and *Chlidonias niger* [black tern] are examples of species that are not established in Norway, but may occur as visitors. Because they reach Norway without anthropogenic involvement, they are not to be risk-assessed. While *B. musculus* is a regular visitor (migrant) and is therefore regarded as native, *C. niger* is an irregular visitor (vagrant) and thus neither native nor alien.
- *Larix sibirica* [Siberian larch] has likely been introduced to Norway after 1850. In this case, it is to be risk-assessed as an alien species. Because it is a production species, however, its production area is to be disregarded in the risk assessment. Unaided reproduction on *L. sibirica*'s own plantations is considered as establishment, but not as spread, and is thus to be excluded from estimates of expansion speed. Along the same lines, ecological effects that *L. sibirica* might have on its own production area, do not enter into the risk assessment. Effects outside L. sibirica's production area, on the other hand, are part of the risk assessment. This includes ecological effects within the production area of *other species*, e.g. if it should displace native species on the production area of *Ovis aries*.
- Traditional production species are exempted from risk assessments. This concerns several animal species (such as *Anas platyrhynchos*, *Anser anser domesticus*, *Bos taurus*, *Canis lupus familiaris*, *Capra hircus*, *Equus caballus*, *Felis catus*, *Gallus gallus domesticus*, *Ovis aries*, *Sus scrofa domesticus*) and numerous vascular plants (including *Avena sativa*, *Brassica oleracea*, *Hordeum distichon*, *H. vulgare*, *Secale cereale*, *Daucus carota* subsp. *sativus*, *Triticum aestivum*).
- *Tilia × europaea* [common lime] is an alien species that has been much used as a park tree. Under current conditions it does not reproduce in Norway. Nevertheless, *T. europaea* is to be risk-assessed if it can be shown do have distance effects: the nectar of the tree is hypothesised to be toxic for native bumblebees, and this poisoning, if corroborated, affects bumblebee populations in an area that is many times greater than *T. europaea*'s production area.

2.7. Quantifying the presence and state of populations

The presence of individuals of a species can be measured in a number of ways, including population size, area of occupancy and extent of occurrence. As these measures capture different aspects of presence, all of them are to be provided (or at least estimated). The state of a species can be described using demographic parameters such as generation time, population growth rate and carrying capacity. These terms are defined below:

2.7.1. Individual

Individuality is an intuitive and unproblematic concept in for instance arthropods or vertebrates. In other taxa, the concept may be more difficult to implement. As a general definition, we assume:

> **An *individual* is an anatomically, physiologically, behaviourally and/or reproductively autonomous organism.**

In clonal, colonial or modular organisms, these different delimitations will not necessarily be congruent, rendering the definition potentially ambiguous (Wilson 1999). What is counted as an individual will in such circumstances have to be treated pragmatically. The crucial criterion should be that individuals form units that can *reproduce independently from each other*. An important concept is, therefore, that of the mature individual:

> **A *mature individual* is an individual that, judging from its state (such as age, size etc.) is able to reproduce.**

This definition applies irrespective of the means of reproduction (e.g. sexual or asexual, allogamous or autogamous). In clonal organisms, each separate unit (*ramet*) is counted as a mature individual (*not* the *genet*; cf. IUCN 2016:21–24). For fungi, lichens and mosses, special guidelines have been devised, which define individuals based on the overgrown area and/or the number of localities (Brandrud 2015, Hassel et al. 2015, Timdal 2015).

2.7.2. Population size

Population is, in accordance with IUCN's (2012:10, 2016:20) usage, defined as follows:

> **A species's *population* in Norway (or in a specified area) refers to the total number of individuals of that species in Norway (or in the specified area).**

When estimating population *size*, however, only *mature* individuals are to be counted:

> **A species's *population size* in Norway (or in a specified area) is measured as the number of mature individuals of that species in Norway (or in the specified area).**

This definition is used *without exceptions*, and other indices of abundance are *not* to be used.*

Population size as such does not constitute a criterion in risk assessment. However, it is important background knowledge that describes the species's status in Norway. In addition, population size is one of the parameters entering into the estimation of population lifetime (criterion A).

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* In a Red List context, a number of exceptions accompany the definition of population size (IUCN 2012:10, 2016:21–24), but these are *not* to be applied when risk-assessing alien species. The reason is that the precautionary principle has different meanings in red- and black-listing: a cautious estimate is an *under*estimate of the size of a *threatened* population, but an *over*estimate of the size of an *alien* population.

2.7.3. Occurrence

Standardisation across taxa of the term *occurrence* is not trivial. This is solved as follows:

> **An *Occurrence* of a species is here defined as a grid cell of 2 km × 2 km that is inhabited by individuals of the species, and that is essential for the survival and reproduction of these individuals.**

Cases of vagrancy are not counted as occurrences in this sense. A grid cell is regarded as 'essential' if the species reproduces, forages, finds shelter, overwinters in it, etc. If several separate subpopulations of a species occur in one grid cell, they are still counted as one occurrence.

2.7.4. Area of occupancy

The *area of occupancy* (**AOO**) is an estimate of *the specific area which is inhabited by the species and which is essential for its individuals* (Figure 2c). In accordance with IUCN's (2016:46–53) recommenddations and the above definition of occurrence, the area of occupancy is to be understood as the number of occurrences multiplied by the area of the grid cells (4 km^2):

> **Area of occupancy = number of occurrences × 4 km^2**

This definition is to be used for all habitat types (including 'linear' habitats such as rivers, coastline etc.). Areas of occupancy should be based on the standardised 2 km grid defined by Statistics Norway (SSB2KM; Strand and Bloch 2009).

2.7.5. Extent of occurrence

The *extent of occurrence* (**EOO**) "measures the spatial spread of the areas currently occupied by the taxon" (IUCN 2012:11-12, 2016:43–44):

> ***The extent of occurrence* is the area of the smallest convex* polygon that can be drawn to encompass all occurrences of the species (Figure 2b).**

Since the extent of occurrence may include grid cells that are not actually occupied by the species, it can never be smaller than the area of occupancy.

Under special circumstances, the extent of occurrence may be divided into several polygons. This may be appropriate in cases of disjunct distributions (e.g., a species that only occurs in Eastern Finnmark and Southern Norway); or of separate reproductive areas and wintering areas. In such cases, the extent of occurrence is estimated as the sum of these polygons. The reasons for such divisions have to be provided in the documentation.

2.7.6. Generation time

Generation time is a crucial demographic parameter and is here defined as follows:

> ***Generation time* is the average age of reproducing individuals (in years).**

'Reproducing individuals' is here understood as individuals that actually produce viable offspring (not the mean age at maturity). Generation time may be difficult to estimate in certain taxa. A few guidelines may be useful here (cf. IUCN 2016:24–26):

* A polygon is *convex* if none of its interior angels exceeds 180°.

- In *semelparous* species (which only reproduce once in their lifetime), generation time equals the average age at reproduction.
- In *iteroparous* species (which reproduce several times in their lifetime), generation time T is larger than the age α at first reproduction and lower than the age ω at last reproduction. Note that α is usually larger than the age at maturity.
  - If a life table exists for a species, generation time can be estimated rather precisely.* Otherwise, generation time has to be approximated.
  - In species with an annual adult mortality rate m that is known and (more or less) age-independent, $T \approx \alpha + m^{-1}$ is a convenient approximation of generation rime (where $0 < m \leq 1$).
  - In plants with seed banks, the half-life of seeds should be included in estimates of generation time.
- For fungi, lichens and mosses, special guidelines have been devised, which define generation time based on the lifestyle (1 to 33 years; Brandrud 2015, Hassel et al. 2015, Timdal 2015).
- It will often be possible to infer generation time from closely related species.

Generation time does not as such enter into the risk assessments. However, it is essential for describing the species's reproductive potential. Furthermore, the time frame of ecological effects is defined as five generations (for species with generation times between 10 years and 60 years; otherwise, the time frame is 50/300 years for species with shorter/longer generation times, respectively).

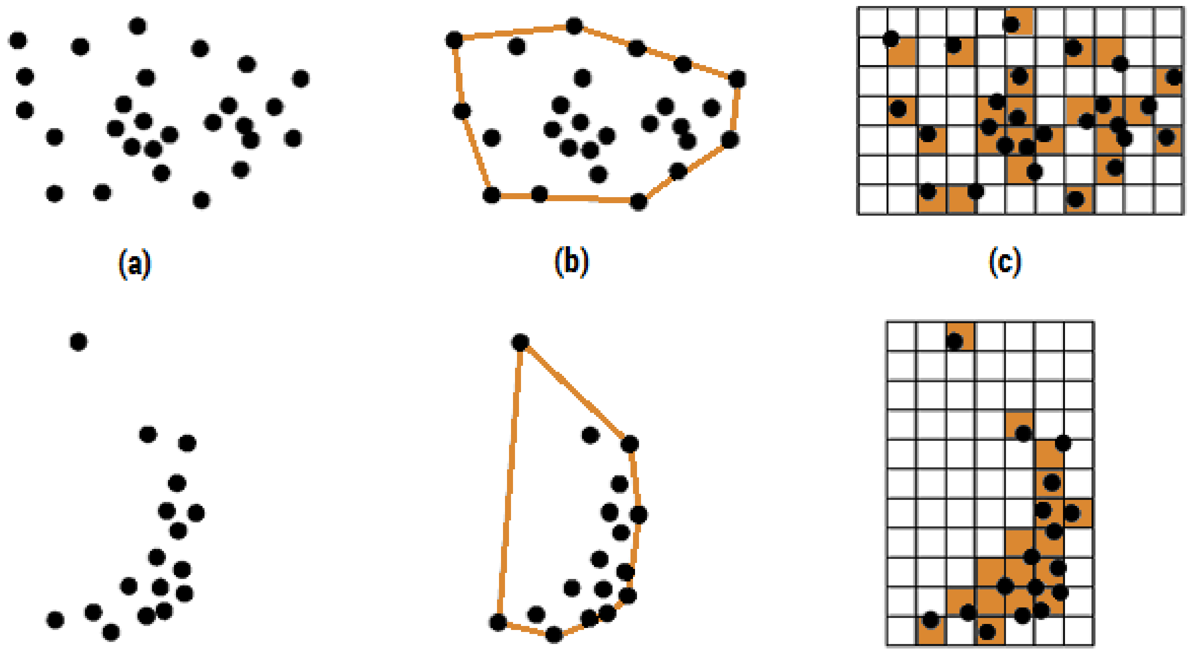

Figure 2: AAO and EOO. (a) Two populations are illustrated using points for each subpopulation. **(b)** The line delimits the populations' *areas of occupancy* (AOO). **(c)** The sum of the orange squares (symbolising occupied grid cells of 2 km × 2 km) determines the populations' *extents of occurrence* (EOO). (Source: IUCN 2012, modified)

* As $T = \sum_{x=\alpha}^{\omega} x p_x f_x / \sum_{x=\alpha}^{\omega} p_x f_x$, where the summation is over the cohorts with age x, p_x is the survival rate from birth to age x, and f_x is fertility at age x.

2.7.7. Population growth rate

Population growth rate is a parameter describing the (potential) *mean annual increase in population size*:

The multiplicative population growth rate λ (lambda) is defined as $\lambda = N_t / N_{t-1}$.

Here, 'N_t' signifies population size in a given year, and 'N_{t-1}' population size one year earlier. A stable population is characterised by λ = 1, i.e. population size neither in- nor decreases. An increasing population has λ > 1. A decreasing population has λ < 1. An annual population growth of 10% thus corresponds to λ = 100 % + 10 % = 1.1. These guidelines only refer to the *multiplicative* growth rate λ. The demographic literature often prefers the *intrinsic* population growth rate *r*, which is defined as the natural logarithm of λ ($r = \ln\lambda = \ln N_t - \ln N_{t-1}$).

Population growth rate is an important demographic parameter. It is here used in two different contexts: First, it enters into the estimation of an alien species's lifetime (criterion A). Second, if an alien species reduces the population growth rate of a native species (by means of predation, competition etc.), this constitutes an ecological effect of the alien species according to criteria D and E. A reduction in population growth rate means that the population experiences a downward trend, which will ultimately result in extinction (Figure 3a). As far as native species are concerned, population growth rate is thus used as a measure of the *actual* (or *future*) long-term population trend.

In alien species, however, the *potential* annual population growth is the relevant figure. This is the growth rate under optimal conditions (e.g. in the absence of density regulation, see next section). The potential population growth rate can only be estimated using time series with population counts. In the absence of such data, estimates of λ should be sought in the peer-reviewed literature, if necessary from closely related species.

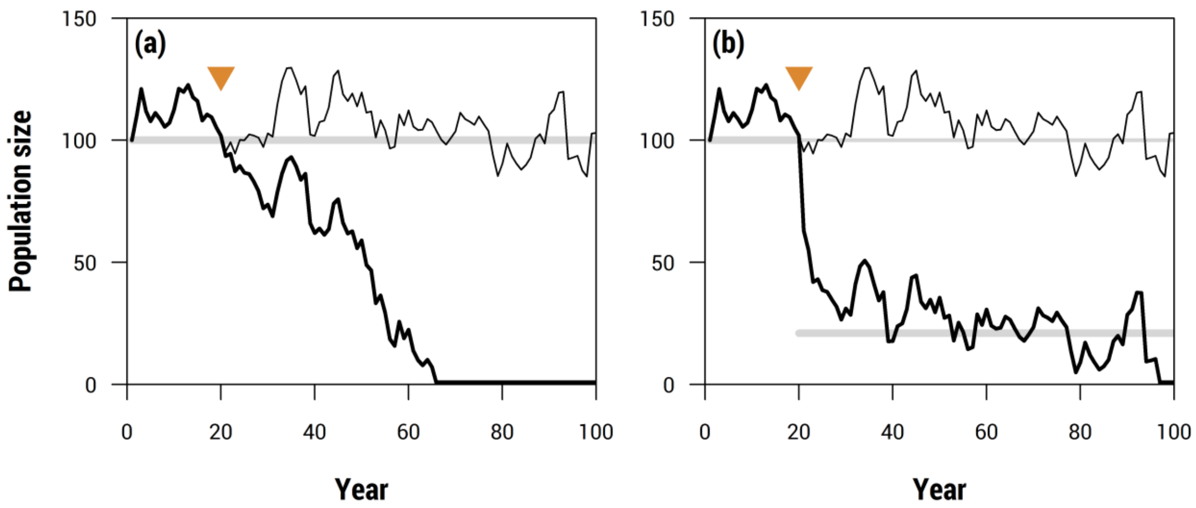

Figure 3: Illustration of population growth rate and carrying capacity. The curves show the population dynamics of a population. The thin line indicates the population trajectory in the absence of disturbance (e.g., by an alien species). The thick line indicates the population trajectory when **(a)** the population growth rate is reduced and **(b)** the carrying capacity is reduced. The change in growth rate / carrying capacity occurs at the time marked by the orange arrowhead. The horizontal grey lines indicate the respective populations' carrying capacities. A negative growth rate will inevitably lead to extinction; a reduced carrying capacity will do so only if the population fluctuations (or the environmental variance) are sufficiently large.

2.7.8. Carrying capacity

The carrying capacity of a population is the size at which the population is stable, i.e. at which there is an equilibrium between factors that increase population size (viz. growth rate) and factors that decrease population size (so-called density regulation). A formal definition of carrying capacity (usually abbreviated *K*) is, therefore:

> **Carrying capacity *K* is the population size at which density regulation balances population growth.**

Density regulation entails that the population growth rate is often negatively related to density (number of individuals per area). This may be due to decreasing fertility or increasing mortality, caused by intraspecific competition.

If an alien species reduces the carrying capacity of a native species (by means of predation, competition etc.), this constitutes an ecological effect of the alien species according to criteria D and E. A reduced carrying capacity means that the population fluctuates at lower average numbers, which increases the risk of extinction (Figure 3b).

2.8. Ecological impact

Risk assessments of alien species are meant to quantify the alien species's *negative ecological impact on Norwegian nature*. The ecological impact exerted by alien species on native nature is proportional to the area colonised, the density attained on this area, and the per-capita effect on Norwegian nature (Parker et al. 1999):

> **Impact = area × density × per-capita effect**
> **= area × per-locality effect**

Population density and per capita effect can be integrated into a measure of ecological effect 'per locality', so that impact becomes a product of two entities. A species's impact will be small as long as one of those factors is small, irrespective of how large the other one is. This is the rationale behind the two-dimensional risk matrix chosen (see Figure 6 on page 32).

The colonisation of Norwegian nature is a dynamic process. Therefore, impact is not estimated from the area currently occupied by an alien species, but from its *expansion speed*, i.e. from the *rate of increase* of the area occupied (measured as the *annual increase of the radius*, see section 5.1.2.).

What is to be assessed is the negative ecological impact of alien species on Norwegian nature. This means that the risk assessment is *not* meant to take account of

- *positive* ecological effects,*
- negative or positive *anthropocentric* effects, e.g. on human health, economy or aesthetics.

As far as *ecosystem services* are concerned (cf. Appendix VII), their ecological dimension is captured by criteria F and G. The monetary dimension, on the other hand, like other economic and anthropocentric aspects, falls outside the scope of the risk assessments.

To the degree that information about positive ecological effects or about anthropocentric effects is available, it ought to be documented together with the general description of the species. However, this information does not affect, nor enter into, the risk assessment itself.

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* The effect of a species can be regarded as positive if, seen in isolation, it increases the survival or fertility of a native species (facilitation) or if it stabilises a nature type. At the *community level*, the situation will be more complex, however, rendering facilitation a somewhat controversial concept. Since positive ecological effects are not assessed here (and are not weighed against negative ones), this question does not affect the assessments.

2.9. Uncertainty, risk and dark figures

2.9.1. Uncertainty

All empirical evidence is always imbued with uncertainty (cf. Popper 1934), this includes all estimates and measurements. There are, however, three very different sources of uncertainty: *natural variability*, *measurement or observation error* and *semantic uncertainty* (Akçakaya et al. 2000, EFSA in prep.):

- The parameter one tries to estimate, *actually* takes different values at different times or places. To illustrate this with examples from alien species, expansion velocity of a single species may vary over time, and its ecological effects may differ between northern and southern Norway. This may be due to environmental or demographic stochasticity (noise), or due to environmental gradients and similar factors. A single measurement, even it were perfectly precise, will thus not necessarily be representative of other points in space or time.
- In addition, all estimates are subject to measurement or observation error, which may be reduced, but not entirely removed using improved methods. The time of first introduction of a species will for instance usually be unknown – it may take several decades before an introduced species is reported for the first time. Along the same lines, an estimate of the area of occupancy or of population size is a function of two factors: (1) whether the species is actually present at a given locality (presence), and (2) whether the species is discovered *given that* it is present at that locality (*observability*). In reality, observability is always less than 100%.
- The uncertainty that lies in ambiguous wording is referred to as semantic (e.g., unclear definitions, vague questions, imprecise threshold values). By using a purely quantitative set of criteria, the semantic uncertainty is reduced to a minimum in this risk assessment (see Appendix III for elaborations).

To conclude, uncertainty is always *present*, but it will greatly vary in *magnitude*. This fact can be difficult to disseminate to users, who may mistake uncertainty for ignorance. It is crucial for the scientific integrity of the risk assessment, however, that uncertainty is quantified and reported.

In the presence of uncertainty, estimates do not normally have the nature of point estimates (e.g., 'expansion speed was estimated to 97.42 meter per year'). Rather, they follow a probability distribution (Figure 4). Empirical estimates should thus always be presented by means of two figures:

1) **The best available evidence should be presented in terms of the median (or 50th percentile*).** The guidelines that IUCN (2016, especially p. 18f.; cf. Artsdatabanken 2014, especially p. 17) has prepared in the context with red-listing, is that a risk assessment ought to be *precautionary, but realistic*. This entails that, in cases of doubt, a somewhat higher value than the median may be provided, but no higher than the 60th percentile. Figure 4 visualises the 60th percentile as an orange dot, and the median as a vertical line.
2) **Uncertainty should be presented in terms of the interquartile range (or 50% confidence interval).**** Uncertainty (e.g., as expressed by the standard deviation) will often be rather large when predicting future values of ecological variables. Therefore, 95% confidence intervals are too wide for this purpose. Figure 4 visualises the interquartile range as a grey area.

In many cases, a statistical estimation of the variables of interest will not be feasible. While a number of measurements may exist, their underlying distribution will then be unknown and inestimable. In such cases, risk assessors are asked to produce an expert opinion of the median plus the lower and

* The *n*th *percentile* is the smallest number that is greater than (or equal to) *n*% of the values in a set or a probability distribution. The median is thus the 50th percentile (or second quartile) of a distribution.

** The *interquartile range* is the interval between the *lower quartile* (25th percentile) and the *upper quartile* (75th percentile) of a distribution, and is thus equivalent to the 50% confidence interval of the distribution.

upper quartile. The abovementioned rules apply to such cases, too: based on the available knowledge, one should try to envisage the interval that contains the true values with a likelihood of 50% (or, if there are sufficiently many measurements, the interval that contains 50% of these measurements). Within this interval, the median is identified (or, in cases of doubt, a value that is somewhat higher, or more 'pessimistic', than the median, but not higher than the 60th percentile). If the interval is expected to be asymmetric, the estimate should take this fact into account. (Figure 4b is for instance skewed to the right; here, the 60th percentile is more displaced to the right than in a symmetric distribution.)

It is important to emphasise that uncertainty – even if it is always to be reported – will not always affect the score assigned to the species. This may be illustrated using criterion B:

- If expansion velocity is estimated to be 100±40 metres per year, the entire confidence interval (60–140 metres per year) lies within score 2 (i.e., *between* the threshold values of 50 and 160 metres per year, respectively). The risk assessment is in this case unaffected by the uncertainty.
- If expansion velocity is estimated to be 40±20 metres per year, the confidence interval (20–60 metres per year) overlaps with two scores; i.e., the threshold delimiting score 1 from 2 (50 metres per year) is within the confidence interval. In this case, the risk assessment is affected by the uncertainty.

Uncertainty regarding ecological effects is handled according to the same principles. Not all ecological effects are measured on a continuous scale, however. This requires some adjustments in the methodology, which are explained in section 5.0. below.

2.9.2. Risk

The *risk* of an event is in general defined as the *product of the consequences (magnitude, damage, cost) and the probability of the event*:

Risk = consequences × probability

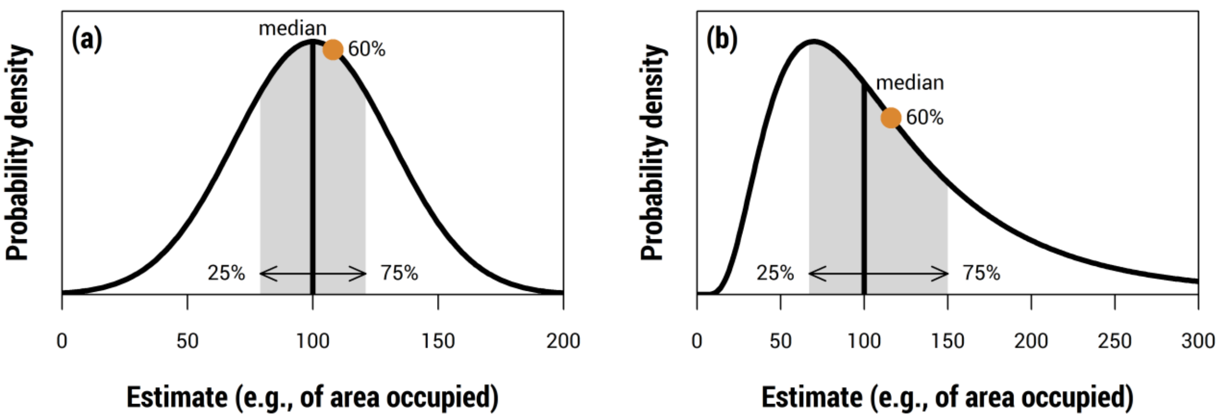

Figure 4: Examples of probability distributions. Estimates of empirical quantities follow a probability distribution, here exemplified by **(a)** a symmetrical (normal distribution) and **(b)** an asymmetrical (log-normal) distribution. The vertical line shows the median (entailing that it is equally likely that the true value is above and below this value). The grey area emphasises the interquartile range (or 50% confidence interval), i.e. the interval that contains the true value with a likelihood of 50%. The interquartile range is enclosed by the 25th percentile (lower quartile) and the 75th percentile (upper quartile). The 60th percentile is marked by the orange dot.

Consequently, the risk of an event is zero (or infinitesimal) if its probability is zero (or infinitesimal), even if the consequences are huge. Likewise, the risk of an event is zero (or infinitesimal) if its consequences are zero (or of infinitesimal magnitude), even if the probability is high. For a risk to be significant, both the magnitude of its consequences and its probability have to be greater than zero, and at least one of them must be large.

The risk that is assessed when it comes to alien species, is the ecological damage they can do to Norwegian nature. The risk matrix used (Figure 6 on page 32) distinguishes between ecological effect and invasion potential, which must not be confused with the definition of risk. Both axes of the risk matrix express risks: the *risk of invasion* (magnitude × probability of invasion) on the *x*-axis and the *risk of ecological effects* (magnitude × probability of ecological effects) on the *y*-axis. The final impact category expresses the *risk of impact on Norwegian nature*, which can be seen as the product of two risks:

risk of impact
= risk of invasion × risk of effect
= (probability of invasion × magnitude of invasion) × (probability of effect × magnitude of effect)
= (probability of invasion × probability of effect) × (magnitude of invasion × magnitude of effect)
= probability of impact × magnitude of impact

All the variables that enter into the risk assessment are uncertain, and the abovementioned rules on uncertainty thus apply (cf. section 2.9.1.). Many magnitudes of damage are thinkable, and they will follow an (normally unknown) probability distribution. The risk assessment should be based on the consequences (i.e., the ecological effects or the invasion potential) that lie – or are estimated to lie – within the 50% confidence interval (interquartile range) of this distribution. This means that the upper and lower 25% of the distribution should be discounted. Therefore, the assessments should not be based on rather improbable consequences, even if their magnitude would have been large.

2.9.3. Dark figures

The detectability of organisms is below 100% (see section 2.9.1.), and the *known* population measures are thus always lower than the *real* measures. Estimates of the (unknown) real values are important, because it is the actual population that affects nature, not merely its known fraction. The known values are important, too, since these are documented and constitute the basis for estimates of the real value. Therefore, both values shall be reported. The ratio between the estimated total number and its known fraction is referred to as dark figure:

A *dark figure* is the factor by which the *known* number/area has to be multiplied in order to obtain the *estimated total* number/area (total = known × dark figure).

Because of incomplete knowledge of occurrences, the dark figure is a crucial concept for many of the species that are risk-assessed. In sufficiently large datasets, it is possible to estimate dark figures from the data themselves (cf. Appendix XI). However, in most cases, the dark figures have to be based on the risk assessors' educated opinion. This educated opinion should take the known occurrences and the species's habitat requirements into account and combine them with information on the area of occupancy of the relevant habitats. The dark figure is also affected by the sampling effort (the more underreported a species is, the larger are its dark figures).

Since the total numbers/area are unknown, the dark figure itself is necessarily uncertain, too. Therefore, what has been said about uncertainty above (cf. section 2.9.1.), also applies to dark figures: dark figures should be reported in terms of a best estimate (median) and a 50% confidence interval.

3. Species information

The species information collected in the AlienSpeciesDatabase is distributed over five tabs, which are described in the following five sections (species status, species characteristics, entry, pathways, distribution history). This information does not affect the risk assessments as such, but nonetheless represents important knowledge, e.g. because it may be relevant for management.

3.1. Species status

Each species has to be assigned to one of the following five statuses:

1) Alien species within the delimitations that is observed and established in Norway (i.e., it is documented or likely that it reproduces unaidedly outdoors, cf. section 2.4. In cases of uncertainty about this status, see sections 2.1. and 2.6.1. for how to proceed).
2) Alien species that is documented to have an ecological effect in Norway, yet is not established.
3) Door knocker (having the potential to establish in Norway within 50 years; see section 2.5.).
4) Regionally alien species (see section 2.6.2.).
5) Species that does not fulfil (a) the definition or the (b) historical, (c/d) ecological or (e) taxonomical delimitation (cf. sections 2.1. and 2.6.):
   (a) the species is not alien (vagrant, migrant, or established without anthropogenic introduction);
   (b) the species has been established with a stably reproducing population in Norway as of 1800;
   (c) the species is a traditional production species (for definition, see section 2.3.);
   (d) the species is unlikely to become established in Norway within 50 years;
   (e) the taxon is ranked below the species level and shares the status of its 'parent species'.

Species assigned status 1 or 2 *are* to be risk-assessed. Species assigned status 3 or 4 *are* to be risk-assessed *if* an assessment is requested (see Appendix VIII), and *can* be risk-assessed if experts see a need. Species assigned status 5 are *not* to be risk-assessed. The reason for placing a species in category 5(a), 5(b), 5(c) or 5(d), has to be described and documented in the text box.

NB! *The choices made regarding species status will affect the availability (and to some degree the appearance) of the following tabs (sections 3.2. to 5.5.).*

In addition, the following information is required:

- *First observation in Norway:* the time and place of the first documented observations of the species are to be entered, separately for different developmental states and environments.
  - States: immature *individuals* / *mature individuals* / *viable offspring* (produced unaidedly) / population (> 20 *individuals* at the same *locality*; terms in italics are defined in the glossary).
  - Environments: outdoors / on production areas / in Norwegian nature (terms are defined in section 2.3.).

  NB! *Since this information will be used as a filtering criterion, it is important that relevant cells contain text* (especially the rightmost cell relevant and the lowest cell relevant). Therefore, if year or place are unknown for a state known to (have) exist(ed), the cell should contain the text 'unknown'.
- *Previous ecological risk assessment:* has the species been risk-assessed previously, in Norway or elsewhere? In the latter case, provide a reference and short description of the assessment.

3.2. Species characteristics

The description of background information that is to be provided for all relevant species, contains:

- *Images:* on top of the tab, there is an e-mail link that should be used to send in images of the species. Accepted file formats are JPG, PNG and GIF. Required information includes the full and correct names of photographer and institution plus licence (either CC BY 4.0 or CC BY-SA 4.0). Other information (date, place, sex, developmental state, habitat etc.) should be provided where relevant.
- *Lifestyle:* is the species (for endoparasites: its hosts) living in marine, freshwater and/or terrestrial environments?
- *Original distribution:* the biogeographic area(s) of origin (including areas colonised unaidedly). Available choices (in addition to 'unknown') are oceans (for marine species) or combinations of continents and climate zones (for all other species):
    - Oceans: Arctic, Atlantic (Northeast, Northwest, Tropical, South), Baltic, Black, Caspian, Indian (Tropical, South), Mediterranean, Pacific (North, Tropical, South), Southern Ocean/Sea.
    - Continents: Europe, Africa, North [incl. Central] America, South America, Asia, Oceania [incl. Australia].
    - Climate zones: polar, temperate (boreal, nemoral, arid), subtropical (medditerranean, humid, arid, mountainous, Cape, unspecified), tropical

  For definitions and delimitations of climate zones, see Appendix VI. A more detailed description of the original distribution may be given in the text box.
- *Current distribution:* the biogeographic zone(s) encompassing the current distribution of the species, understood as the sum of the original distribution and areas to which the species has been introduced anthropogenically. Only areas in which the species are *established*, are to be indicated. The choices available are the same as for the previous question.
- *Temperature:* for freshwater species, it is to be indicated whether they can survive below 5°C.
- *Arrived in Norway from:* does/did the species arrive to Norway from (one of) its area(s) of origin, or via another place (e.g., secondary spread from neighbour countries; introduction via alien populations in other countries)? For regionally alien species, the option 'Norway' is available, too. A more detailed description may be given in the text box.
- *Reproduction:* the means of and potential for reproduction. Indicate whether the species is able to reproduce sexually and/or asexually (generally, not only under Norwegian conditions). Generation time (see section 2.7.6.) is to be provided in years. If generation time differs between Norway and elsewhere, the *lowest* estimate should be provided.
- *Other effects:* where relevant, effects falling outside the scope of this assessment (i.e., other than negative ecological effects in Norway) should be provided:
    - Health effects: does the species affect the health of human beings or production species; and if so, how?
    - *Economical effects:* does the species have negative or positive economical effects; and if so, for which sector or industry and in which monetary order of magnitude?
    - *Effects on ecosystem services:* does the species affect ecosystem services; and if so, which? A definition and survey of ecosystem services is provided in Appendix VII.
    - *Positive ecological effects:* can the species be said to have positive* effects (facilitation) on native species or nature types; and if so, which effects and on which species / nature types?
    - *Effects of the source population:* does the removal of individuals have a negative effect on the source population (e.g., when the species imported is threatened in the exporting country)?

  Absence of (known) other effects should be described as 'no known effect'. Empty fields will be interpreted as absence of information.

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* In accordance with the footnote on page 20, it suffices to mention effects that can be regarded as positive when seen in isolation.

3.3. Entry

This tab covers the intentional import and unintentional transport of the species from abroad into 'indoors Norway' (e.g., private homes, shops, storerooms etc.) or to the production area of the species. Such a species is not regarded as *introduced* as long as it is not released into *Norwegian nature* (according to the definition of section 2.1. and 2.3.). Not all alien species go through an entry phase, since some species can be introduced directly into Norwegian nature without a detour through indoors environments or production areas. Of the species imported, some are still door knockers, while others are introduced to, and potentially established in, Norwegian nature. Introductions from indoor environments can occur by release (intentionally) or by escape (unintentionally). On this tab, only the entry phase is to be described, not the release or escape (which is covered by the next tab).

Tick off the check box if an entry phase occurs. Thereafter it is possible to choose pathways of entry from a list. Pathways of entry are grouped into three categories: direct import, contamination and stowaways. The latter two are explained in section 3.4, and a complete list of their subcategories can be found in Appendix IV. Subcategories of direct import are:

- to agriculture (of plants)
- to forestry (of trees)
- to plant sale (plant shops, flower shops, garden centres, nurseries etc.)
- to parks and green spaces (of ornamental plants)
- to farms (of farm animals)
- to fur farms
- to aquaculture/mariculture
- to sale of live food or live bait
- to animal sale (of pet/aquarium/terrarium species etc.)
- directly to user by mail
- private self-import
- to botanical gardens / zoos / aquaria
- to research
- to other or unknown goals (details to be provided in text box)

After having selected a pathway, the following information needs to be provided:

- *Frequency:* how often does entry along this pathway happen (or has happened or will happen)? Available choices:
  - less than once per decade
  - one to several (c. 8) times per decade
  - c. once per year (c. 9–19 times per decade)
  - several times per year
  - unknown
- *Abundance:* how many individuals are imported per event? An estimated average is to be provided within these intervals: 1 / 2–10 / 11–100 / 101–1000 / > 1000 / unknown.
- *Period:* using the following choices, it is specified whether entry along this pathway is
  - only historical (discontinued, and will not start again)
  - discontinued, but may start again
  - current
  - only in the future
  - unknown

If the latter three questions are answered with 'unknown', an explanation has to be provided in the text box.

3.4. Pathways of introduction and spread

Means, mechanisms or events that result in a species being **introduced** to, or **spread** within, Norwegian nature, are referred to as *pathways*. Knowledge of pathways is crucial for effective management measures. In addition to indicate the pathways as such, the information collected on this tab is important for being able to quantity the *propagule pressure* (frequency of introduction events multiplied by abundance per introduction event).

The tab consists of a list that has to be populated with the pathways available in the menu. All relevant pathways are to be provided, one by one. The classification of pathways follows an international standard, so that every introduction can be assigned to one out of six categories and one of its subcategories (see Appendix IV for a list of these). Sorted by decreasing involvement of humans, the categories are:

1) *release* (intentional);
2) *escape* (from containment, such as farms, gardens, aquaculture, fields etc.);
3) *contamination* (introduction of infected or parasitised animals, plants or organic material);
4) *stowaway* ('hitchhikers' during the transport of humans, luggage, bulk, vehicles etc.);
5) *corridor* (independent spread through man-made waterways, land bridges or tunnels);
6) *unaided spread* (natural dispersal from populations whose presence is due to 1–6).

After having selected a pathway, the following information needs to be provided:

- *Introduction/spread:* is the pathway selected a pathway of introduction to Norwegian nature, or a pathway of spread within Norwegian nature? It is important to distinguish between a species's means of entering Norwegian nature (from abroad, from production areas or from indoors environments) and means of spreading further (from existing occurrences in Norwegian nature).
- *Frequency:* see explanation and available choices in section 3.3.
- *Abundance:* see explanation and available choices in section 3.3.
- *Period:* see explanation and available choices in section 3.3.

Table 1: Information to be provided about the current and future distribution (tab 3.5.). Grey cells are calculated automatically. (In addition, county-wise occurrences are to be indicated using check boxes.)

	known figures	dark figures			estimated total figures		
		low	best	high	low	best	high
Current							
population size	120000	5	10	20	*600000*	*1200000*	*2400000*
Area of occupancy	48	4	8	16	*190*	*380*	*770*
Extent of occurrence	200						
Potential							
Area of occupancy					200	500	1000

3.5. Distribution history

This tab collects the relevant knowledge about the historical, current and potential distribution of the species in Norwegian nature, as well as the situation abroad. For definitions, see section 2.3. for Norwegian nature; section 2.7. for population size, area of occupancy (AOO) and extent of occurrence (EOO), and section 2.9.3. for dark figures. These definitions entail that only outdoor observations of mature individuals should be included in calculations; for production species, their own production area has to be disregarded.

- *Distribution history in Norway:* information about the distribution at earlier times is collected in a list, with the aim of documenting changes in distribution over time. The list is populated by pressing the 'add' button and providing values for the cells in the input frame. Data may be provided for different time periods (single years or longer intervals) and/or different areas separately. Data can be added manually, or by importing geo-referenced observations directly from the Species Map Service (by pressing the 'show Species Map Service' button).
  The data and the type of observations that are important from the Species Map Service can be changed using the 'selection parameters' button. If certain parts of the AOO need to be excluded, this can be done by drawing a polygon (press the pentagon symbol in the left margin of the map): data points outside the polygon will be ignored. Upon pressing the 'transfer data' button, values and county-wise occurrences are imported to the AlienSpeciesDatabase, but may be adjusted manually. Dark figures have to be provided manually, too. Likewise, the likely county-wise occurrences are filled in automatically based on the known occurrences, but may be changed.
- *Dataset:* datasets documenting the distribution history may be uploaded using the 'upload' button at the bottom of the panel (see section 1.4. on uploading data).
- *Current and potential distribution:* this information is especially important, because it is used when estimating the expansion speed (see section 5.1.2.), and possibly the population lifetime (5.1.1.). The information on current distribution is to encompass estimates of population size, AOO, EOO and county-wise occurrences as of 2016. The potential distribution is described in terms of estimates of the AOO and county-wise occurrences 50 years from now (i.e., as of 2066). Potential distribution is to be provided for established species as well as door knockers, while the latter do not have any current distribution. Figures can be transferred from the previous panel ('Distribution history in Norway') by selecting the desired time period and pressing the 'copy to current/potential distribution' button.
  Population size (number of mature individuals) and AOO (km^2) are to be reported using (a) the known figures; (b) a low, (c) best and (d) high estimate of the dark figures. Uncertainties in the known figures should be included in the interval provided for dark figures. The estimated total figures are calculated automatically as the product of known and dark figures. The low, best and high estimate of the potential AOO is to be provided in km^2 including dark figures. Low and high estimates should be based on the lower and upper quartile (see section 2.9.1.). Table 1 illustrates the information to be provided using some arbitrary numbers as examples.
  In order to facilitate the estimation of potential AOOs, the areas of bioclimatic zones and sections of Norway are provided in Table 2. As an aid in approximating the temperature increase until 2066, some average projections are provided in Table 3. Similar projections are available for other climate parameters (e.g., precipitation, length of growing season) from the Norwegian Climate Service Centre (https://klimaservicesenter.no/faces/desktop/scenarios.xhtml).
  Assumed and potential county-wise occurrences will be pre-set using the known occurrences. 'Assumed' here refers to undocumented current occurrences, while 'potential' refers to likely future occurrences. The pre-set tick marks may be changed manually.
  The basis for or assumptions behind estimates should be specified in the text box. This may for instance include the background of projections, assumed critical parameters, expected changes

in the characteristics of the species, its environment or its pathways, all of which may affect the distribution.

- *Proportion within highly modified nature:* here, an estimate is to be provided of the percentage of the current AOO of the species in Norway that lies within highly modified nature (for definition of the latter term, see Table V-2 in Appendix V).
- *Distribution history in Norway:* the change in distribution over time is to be described in a text box, too. This text will be a part of the documentation, and is supposed to provide a summary of the history of spread of the species in Norway.
- *Distribution history in other countries:* in this text box, the distributional situation of the species in other countries should be described, with emphasis on alien populations of the species in Europe.

Table 2: Area of bioclimatic zones and sections in Norway. All figures are km^2. (Source: Moen 1998:144)

Bioclimatic sections	**Bioclimatic zones** (bor. = boreal)					
	boreonemoral	south bor.	central bor.	north bor.	alpine	**sum**
Strongly oceanic	5 400	4 600	4 200	0	4 300	**18 500**
Typically oceanic	10 100	14 000	21 700	14 700	16 500	**77 000**
Weakly oceanic	7 300	10 000	20 500	25 800	36 300	**99 900**
Transitional section	2 000	10 300	13 400	32 200	38 000	**95 900**
Weakly continental	0	600	3 900	17 400	6 800	**28 700**
Sum	**24 800**	**39 500**	**63 700**	**90 100**	**101 900**	**320 000**

Table 3: Temperature increase in Norwegian regions until 2066. All figures are provided in °C and indicate by how much the average temperatures in 2066 are projected to have increased relative to those in 1971–2002, based on two different emissions scenarios (cf. Hanssen-Bauer et al. 2015). In accordance with the precautionary principles, estimates should mainly be based on scenario RCP8.5. (Source: klimaservicesenter.no)

	RCP4.5			**RCP8.5**		
Region	whole year	summer	winter	whole year	summer	winter
Østlandet	2.0	1.9	2.4	2.9	2.6	3.2
Vestlandet	1.9	1.7	2.0	2.8	2.7	2.9
Midt-Norge	2.1	1.7	2.4	3.1	2.7	3.2
Nordland/Troms	2.6	2.1	2.9	3.7	3.3	4.0
Finnmarksvidda	3.2	2.2	3.9	4.5	3.4	5.2
Varanger	3.3	3.0	3.8	4.6	4.1	5.0

4. Nature types

The tab 'Nature types' of the AlienSpeciesDatabase collects all information related to nature types, including risk assessments according to criteria C, F and G. These criteria are defined as follows:

[C] The larger the area of a nature type colonised by an alien species, the higher the species scores on the invasion axis. 'Area colonised' here refers to the proportion of the area of occupancy (AOO) of the nature type(s) affected that will contain occurrences of the species within 50 years. This proportion is to be assessed separately for the nature types affected, and the largest proportion determines the score. The threshold values are defined as 5%, 10% and 20%, respectively (Table 5 on page 34; Figure 5).

[F] The larger the area of threatened or rare nature types undergoing change due to an alien species, the higher the species scores on the effect axis. 'Change' here refers to a substantial state change in at least one environmental variable (where 'substantial' is defined below). 'Area' here refers to the proportion of the AOO of the nature type(s) affected. This proportion is to be assessed separately for the nature types affected, and the largest proportion determines the score. The threshold values are defined as 0%, 2% and 5%, respectively (Table 8 on page 43).

[G] The larger the area of other nature types undergoing change due to an alien species, the higher the species scores on the effect axis. 'Other nature types' here refers to nature types that are neither threatened nor rare nor heavily modified. The remaining definitions follow criterion F. The threshold values are defined as 5%, 10% and 20%, respectively (Table 8 on page 43).

Nature types in which the species has been observed, and nature types that constitute a potential habitat for the species in Norway, are both to be indicated on this tab. This is done by choosing relevant nature types from the menu and adding them to a list. All nature types that are of importance for the survival of the species are to be indicated, e.g. if the species utilises different habitats during different life stages.

The system used to classify nature types in the AlienSpeciesDatabase is based on *Nature in Norway* (NiN), which is described online. A summary is provided in Appendix V. In most context, version 2 is to be applied (NiN 2.0; Halvorsen et al. 2015); however, the Red List of nature types still follows version 1 (NiN 1.0; Halvorsen et al. 2009, Lindgaard and Henriksen 2011). *Threatened* nature types are the ones classified as vulnerable (VU), endangered (EN) or critically endangered (CR); *rare* nature types are the ones listed as near threatened (NT) on the basis of a low number of occurrences (i.e., based on criteria 2 or 3 for red-listing nature types; Lindgaard and Henriksen 2011).

Since the Red List of nature types follows NiN 1.0, threatened/rare and other nature types have to be handled in separate lists on the 'Nature types' tab. The information required for the nature types concerned, is, however, identical for threatened/rare and other nature types.

Three hierarchical levels of nature types are available on NiN's *ecological systems* level (major-type groups, major types, basic types). It is not required to indicate nature types at the lowest of these levels. The level to be indicated will vary depending on the specificity of the habitat requirements of the species, as well as on the available knowledge. As far as forests are concerned, the dominant tree type should be provided, too (i.e., whether conifers, broad-leaved deciduous trees, boreal deciduous trees or *Salix* spp. are dominant or sub-dominant). NiN's *microhabitat* level is available for parasites etc.

Heavily modified nature (see Table V-2 in Appendix V) is to be handled as follows: nature types in which the species (can) occur, are to be indicated, even if the nature type is regarded as heavily modified. However, occurrences and expansion of the species in heavily modified nature are disregarded when assessing criteria C, F and G. (The AlienSpeciesDatabase takes this into account automatically.)

After a nature type is chosen (on the desired hierarchical level, and separately for threatened/rare systems, other systems, and microhabitats), the following information should be provided:

- *Time frame:* tick off whether the species occurs in the nature type as of 2016 ('present'), or whether it is likely to colonise this nature type within 50 years ('future').
- *Area colonised:* how large is the highest proportion of the AOO of the nature type that is likely to be colonised within 50 years? *The estimate should include dark figures*. The answer determines the score according to criterion C (Figure 5). Nature types in Norway are not yet mapped, so that their AOOs are not yet known. The question has thus to be answered based on expert judgement. The estimate does not need to be more precise than the threshold values. For criterion C, these are 5%, 10% and 20% of the AOO of the nature type (see Figure 5 and Table 5 on page 34).
- *Substantial state change:* does the nature type undergo (or is it likely that it will undergo) *substantial* state changes due to the presence of the species, and, if so, which? A drop-down list shows relevant environmental variables. Other changes or more details can be described in the text box. Environmental variables are based on NiN's descriptive system. Appendix V (Table V-2) provides an overview of the relevant state changes as well as the definitions and levels of the environmental variables. According to the set of criteria, a state change is regarded as 'substantial' if it encompasses more than a third of the levels defined for that specific environmental variables. If the nature type is undergoing changes for other reasons than alien species, the state change is only regarded as 'substantial' if it encompasses more than a third of the defined levels *over and above* the change that would have occurred in the absence of the species. The number of levels (mostly between one and three) that constitute a substantial change, are indicated in Table V-2 (p. 77) for the relevant environmental variables.

  Please note that effects that parasites exert on their hosts are not to be regarded as state changes in their microhabitat, but as effects on native species. These are captured by criteria D and E.
- *Substantially affected area:* how large is the proportion of the AOO of the nature type that will undergo *substantial* state changes within 50 years due to the presence of the species? The answer(s) to this question determine the score according to criteria F and G (Table 8 on page 43). The explanations for 'area colonised' apply to the affected area, too.

Where relevant (for parasites, saprobionts etc.), microhabitats may be added to a separate list. Areas and state changes are not to be provided. Microhabitats have thus no effect on criteria C, F or G.

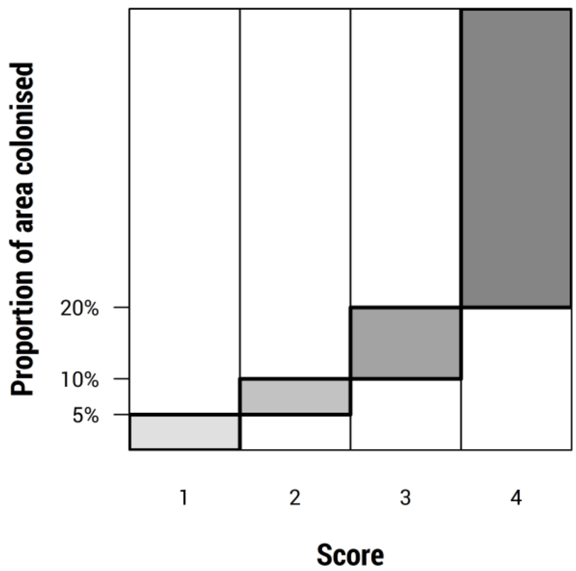

Figure 5: Illustration of criterion C. The score according to this criterion is based on the proportion of the area of a nature type colonised by the alien species.

5. Risk assessment

The risk assessment aims to quantify the *negative ecological impact* that alien species have on Norwegian nature (see section 2.8. for the definition of impact, and section 2.9.2. for the definition of risk). This is accomplished using nine criteria (Table 4), each of which belongs to one of the two axis in the risk matrix – the invasion axis and the effect axis (Figure 6). Accordingly, the risk assessment in the AlienSpeciesDatabase is distributed over two different tabs, one for invasion potential and one for ecological effects. The remaining tabs describe geographic variation, climate effects and documentation.

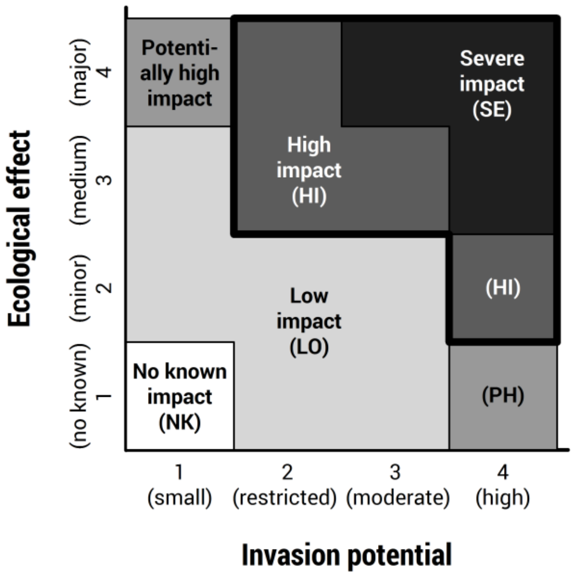

Figure 6: Risk matrix. According to the set of criteria, alien species are assigned to five impact categories (NK, LO, PH, HI, SE), depending on the scores (1-4) they obtain for invasion potential (Table 5) and ecological effects (Table 8, Table 9).

Table 4: Overview of the criteria used in risk assessing the negative impact of alien species on Norwegian nature.

Criterion	Title of criterion	Axis
A	median population lifetime	invasion axis
B	expansion speed	
C	colonisation of nature types	
D	effects on threatened or keystone species	effect axis
E	effects on other native species	
F	effects on threatened or rare nature types	
G	effects on other nature types	
H	transfer of genetic material	
I	transmission of parasites or pathogens	

5.0. Specification of uncertainty

For all nine criteria, the best estimate is based on the information that is fed into the AlienSpecies-Database's tabs 'Invasion potential' and 'Ecological effect', shown by a tick mark (✔). This tick can only be changed by updating the information on the species. Uncertainty, on the other hand, has to be indicated manually with the help of check boxes:

Example 1	Example 2	Example 3	Example 4
☐ score 1 ☐ score 2 ✔ ☑ score 3 ☐ score 4	☑ score 1 ✔ ☑ score 2 ☐ score 3 ☐ score 4	☐ score 1 ✔ ☑ score 2 ☑ score 3 ☐ score 4	☐ score 1 ☑ score 2 ✔ ☑ score 3 ☑ score 4
Score 3 represents the best estimate; uncertainty does not extend beyond the threshold values of this score.	Score 2 represents the best estimate; uncertainty extends to the next lower score.	Score 2 represents the best estimate; uncertainty extends to the next higher score.	Score 3 represents the best estimate; uncertainty extends both ways.

As outlined in section 2.9.1., uncertainty limits are not meant to include all conceivable outcomes, but the 50% most likely outcomes (i.e., the interquartile range or 50% confidence interval). This means that the lowest 25% and the highest 25% of the probability distribution are to be excluded. The main score (the best estimate) should be based on the median, or lie between the median and the 60th percentile.

NB! *Please note that the presence of uncertainty does not necessarily entail that it extends over more than one score.* No assessment will ever be completely certain, but uncertainty will often be contained within the threshold values of the respective score. In this case, only the check box next to the best estimate must be checked. If more than two boxes are checked, a reason has to be provided. Uncertainty cannot extend over more than three check boxes, and not over more than one box up- or downwards.

The threshold values on the invasion axis are given on a continuous scale (Table 5). The effect axis, on the other hand, is mainly based on yes/no questions ('does displacement/hybridisation/infection happen?'). Therefore, uncertainty on the effect axis cannot be described using numerical intervals – rather, *uncertainty should here be indicated by checking all scores that have an expected likelihood of more than 25%*, based on the threshold values given in Table 8 and Table 9.

5.1. Invasion potential

Invasion potential is quantified using three criteria (Table 5). Of these, criterion A measures the *viability* of the species and criterion B its *expansion*, while criterion C addresses invasion separately for the *nature type(s)* affected. Viability and expansion cannot be treated in isolation, because a species cannot have a significant impact unless it is able both to establish itself and to expand in Norway. For this reason, criteria A and B are coupled, so that a species cannot be assigned a high invasion potential when one of the criteria receives the minimum score. Criterion C, on the other hand, is independent of A and B: if C obtains a higher score than A and B, it is C's score that determines the placement of the species along the invasion axis.

5.1.1. Criterion A: median population lifetime

> **[A] The higher the median population lifetime of an alien species in Norway, the higher the species scores on the invasion axis. 'Median population lifetime' refers to the time when it is 50% likely that the population in Norway has gone extinct. The threshold values are defined as 10, 60 and 650 years, respectively (Table 5).**

The aim of criterion A is to express the likelihood of a species maintaining a viable population in Norway over time – or, in other words, of the species not going extinct. The lower the *likelihood of extinction*, the higher is the species's *lifetime* in Norway. A high estimated lifetime thus signifies that it is unlikely for the species to disappear all by itself.

The likelihood of extinction is employed by the Red List, too (viz., its criterion E). It has always to be specified relative to a time interval (e.g., 'within 10 years', for critically threatened species). The current criterion A specifies the thresholds in terms of population lifetime rather than likelihood of extinction (see Table 5 and Figure 7). However, both measures describe the same phenomenon and can be readily converted into each other, as shown in Table 6.

Lifetime is itself a statistic quantity. It is, of course, impossible to predict population trajectories many years into the future. Therefore, one cannot foresee the exact lifetime of a species, but merely the *likelihood* that a species obtains a certain lifetime. The *median lifetime* is the lifetime that has a cumulative likelihood of 50% – so that it is 50% likely that the population has gone extinct within the median lifetime. The likelihood distribution of lifetime is strongly skewed to the right, so that the *expected lifetime* (the arithmetic mean of the distribution) is higher than the median lifetime (Table 6).

The lifetime of an alien species is affected by a number of factors, mainly by the size and growth rate of the population, but also by their temporal variability (Lande et al. 2003). Initially, the population size of alien species is determined by the propagule pressure, i.e. by the frequency of, and abundance per, introduction events (Lockwood et al. 2005, Colautti et al. 2006, Blackburn et al. 2009). The growth rate is determined by demographic rates such as fertility, age at maturity and survival. Variability is mainly due to demographic or environmental noise.

Table 5: Criteria, scores and threshold values for the classification of the invasion potential of alien species. [Due to additional conditions (see notes below), criteria A and B are dependent on each other.]

Criterion	**A**	**B**	**C**
Score for invasion potential	Median population lifetime	Expansion speed	Colonisation of nature types
1 (small invasion potential)	< 10 years	< 50 m/a	< 5%
2 (restricted invasion potential)	≥ 10 years [*AND* **B** ≥ **2**]*	≥ 50 m/a	≥ 5%
3 (moderate invasion potential)	≥ 60 years [*AND* **B** ≥ **2**]*	≥ 160 m/a [*AND* **A** ≥ **2**]*	≥ 10%
4 (high invasion potential)	≥ 650 years [*AND* **B** ≥ **3**]**	≥ 500 m/a [*AND* **A** ≥ **3**]*	≥ 20%

* If the additional condition is *not* fulfilled, the score is to be *reduced by one*.

** If the additional condition is *not* fulfilled, the score is defined as the *score of criterion B increased by one*.

NB! *The additional conditions do* not *apply to species that have distance effects or escaped individuals.*

Among population parameters, growth rate λ and carrying capacity *K* (see sections 2.7.7. and 2.7.8.) are of obvious significance: the higher the growth rate, and the higher the carrying capacity, the higher the lifetime. Especially the *population growth rate* is of utmost importance for the viability of the species: if a population has a negative growth rate, it will decrease and ultimately go extinct (see Figure 3 on page 19). If the growth rate is positive, the lifetime is determined by other factors. Newly introduced species will normally have population sizes far below carrying capacity (except when Norwegian conditions are too marginal for the species to prosper). For this reason, *carrying capacity* is often less relevant (in addition to being more difficult to estimate).

On the other hand, stochastic (random) fluctuations can be of central importance. Species that experience extreme population fluctuations are more likely to go extinct due to purely random events. The magnitude of such stochastic effects is quantified using the *variance** of population size. One needs to distinguish between environmental and demographic variance. *Environmental variance* is due to variations in environmental conditions, which affect survival and reproduction of all individuals of a subpopulation alike (environmental stochasticity). Environmental variance is of key importance for population lifetime. As can be seen from Figure 7, environmental variance is a measure of the amplitude of the population fluctuations, which, in turn, determines the probability of the population 'falling over the edge' of extinction.

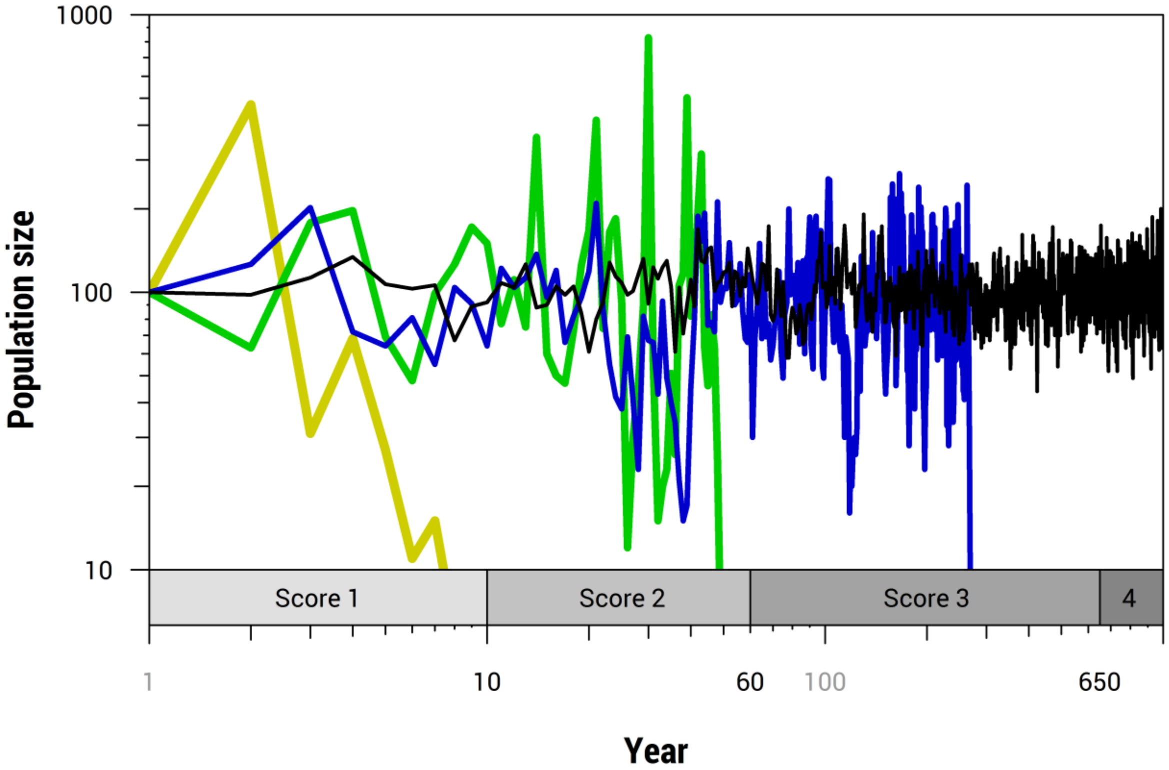

Figure 7: Illustration of criterion A. Example trajectories of population size over time, and time periods used as threshold values for population lifetime. The yellow/green/blue species have a lifetime of < 10/60/650 years, respectively; the black species of > 650 years. The significance of fluctuations is apparent from the figure: the larger the amplitude of the fluctuations (i.e., the larger the environmental variance), the shorter is the lifetime of the species. The four species have *identical* population growth rates (λ = 1.6), carrying capacity (*K* = 100) and demographic variance (σ_d^2 = 0.1), but *different* environmental variance (σ_e^2 = 1.2, 0.8, 0.5, 0.2, respectively). NB: Both axes are on the log-scale.

* *Variance*, commonly abbreviated as σ^2 («sigma-squared»), measures the extent of variation in a dataset.

Certain environmental changes have such a large spatial extent that all individuals of a subpopulation die during the same event. Examples of such ‘catastrophes’ are wildfires, frost or dry spells, or human interference (such as the removal of a compost heap that harbours the entire population). Environmental variance is thus affected by the ecology of the species, but also by the number of subpopulations it has been able to establish. If a species has many subpopulations that are distributed over a large area, and possibly many different habitats, the environmental variance for the total population will be drastically reduced (entailing a very high lifetime). An estimate of environmental variance is, therefore, crucial for quantifying population lifetime.

Demographic variance is due to random variation in the survival and fecundity of individuals (demographic stochasticity). The significance of demographic variance will decrease with increasing population size, because the demographic chance events will tend to cancel each other out. For this reason, demographic variance can often be ignored, except in very small populations.

Most species need a certain minimum population size in order to survive. For example, species with sexual reproduction need at least one individual of each sex, and usually much more than this (e.g., when it is hard to find mates). If the population drops below a certain size, it will go extinct by itself (so-called negative density dependence, or Allee effect). This critical population size is known as the *quasi-extinction threshold*.

Estimation methods

The population lifetime of a species (or its likelihood of extinction) is of course an unknown quantity. There are however several ways of estimating it. The following three methods are supported by the AlienSpeciesDatabase (and listed here in prioritised order):

(a) *Population viability analysis* is the best (most robust) method. However, it presupposes the availability of a time series with annual population sizes from Norway. If such data are unavailable, the second-best alternative is:
(b) *Numerical estimation* of population lifetime based on demographic key parameters of the population (mainly population size, population growth rate and environmental variance). If it is impossible to obtain these key figures, there is a third alternative:
(c) *Red List criteria* may be used (in a somewhat modified manner) as a last solution.

These methods are explained in detail below.

Table 6: Conversion of population lifetime to likelihood of extinction. The threshold values of criterion A are expressed in terms of *median population lifetime* (the 50th percentile of lifetime; the time after which it is 50% likely that the population has gone extinct). The *expected population lifetime* (the arithmetic mean over the likelihood distribution of lifetime) or the *likelihood of extinction* within a certain time frame (as used by the Red List criterion E) are equivalent measures. With the help of this table, the values are readily converted into each other. Bold numbers indicate the threshold values of criterion A (median lifetime) and of Red List criterion E (likelihood of extinction).

Threshold		Lifetime		Likelihood of extinction within			
Criterion A	Red List	expected	median	10 years	20 years	50 years	100 years
1/2	CR/EN	14 years	**10 years**	**50%**	75%	97%	100%
2/3	EN/VU	90 years	**60 years**	11%	**20%**	43%	67%
3/4	VU/NT	950 years	**650 years**	1%	2%	5%	**10%**

(a) Population viability analysis

Population viability analyses (PVA) estimate the likelihood of extinction based on modelled population trajectories. The models, in turn, are based on the observed population dynamics, i.e. on empirical data (counts) from a longer period. The observed population variability over time allows the estimation of demographic parameters, and hence the extrapolation of population trajectories into the future.

PVA is a collective term for several methods. It does not matter which model, or which software, is used, as long as the results are verifiable, i.e. repeatable. There are some good introductions into the topic (Beissinger and McCollough 2002, Morris and Doak 2002), more in-depth treatments (Brook et al. 2000, Bakker et al. 2009, Pe'er et al. 2013), as well as several software packages that perform the calculations required (e.g., Akçakaya and Root 2013, Lacy and Pollak 2014, Stubben et al. 2016). A few examples include PVAs on birds (Sandvik et al. 2014), insects (Schultz and Hammond 2003), vascular plants (Menges 2000, Skarpaas and Stabbetorp 2011) and mammals (Bakker et al. 2009).

Preferably, stochastic PVAs should be used, i.e. models that take account of environmental stochasticity (Lande et al. 2003). The magnitude of environmental stochasticity (i.e., the environmental variance) is one of the parameters that can be estimated from the observed population dynamics (at least if the time series is sufficiently long). By including environmental stochasticity, it is possible to provide prediction intervals for future population sizes (Figure 8). These prediction intervals are useful in quantifying the uncertainty of the lifetime estimate (cf. Sandvik et al. 2014).

If a PVA is used in assessing criterion A in the AlienSpeciesDatabase,

- the result is to be provided in terms of the medium lifetime (in years), preferable with quartiles;
- the methodology used is to be described in the text box;
- the time series used is to be uploaded (on uploading data, cf. section 1.4.).

(b) Numerical estimation

Even if no time series for use in a PVA exist, there will be many cases where data on the demographic key parameters of a species are available. In this case, population lifetime can be estimated numerically (Leigh 1981, Lande et al. 2003:38–40). An **R** script performing the calculations required is available at the URL http://www.evol.no/hanno/12/lifetime.htm. The script does not assume any prior knowledge of **R**, but requires that **R** is installed on your computer. **R** is a free and open language and environment for statistical computing and graphics (**R** Core Team 2016). The above link provides instructions on installation and use.

In order to use this method, estimates of the following parameters are needed:

- current population size (*N*),
- population growth rate (λ, see section 2.7.7.),
- environmental variance σ_e^2 (explained above),
- other parameters, if available (e.g., demographic variance, carrying capacity, extinction threshold).

The abovementioned link (or Appendix X) provides explanations of what these parameters mean, and how they influence the result

For some species, it may be difficult to find reliable estimates of the demographic parameters. Especially as far as alien species in Norway are concerned, few data are available. For most of the variables (although not for current population size), it will be sufficient to use estimates from populations in other countries, or even from related species, as long as their demography, ecology and life history are sufficiently similar.

If numerical estimation is used in assessing criterion A in the AlienSpeciesDatabase,

- the result is to be provided in terms of the medium lifetime (in years);
- the parameter values used (N, λ, σ_e^2; and possibly more) are to be provided.

(c) Red List criteria

If the data required for the two abovementioned methods do not exist (not even from other countries or relevant related species), lifetime may be assessed using Red List criteria A to D. Based on the documentation available, it is decided which Red List category the species would receive in Norway. Using Table 6, the Red List category is then 'reversed', in order to obtain a score for criterion A (critically endangered → 1, endangered → 2, vulnerable → 3, near threatened or least concern → 4).

Red List criteria are applied as described in the guidelines for red-listing (Artsdatabanken 2014) *with the exception that time periods are only to be measured in years*. (Where Red List criteria A and C allow the use of generations instead of year, generations must *not* be used in the current context.) For a survey of the Red List criteria, see Appendix IX.

If Red List criteria are used in assessing criterion A in the AlienSpeciesDatabase,

- the result is to be provided in terms of a Red List category;
- the Red List criterion applied is to be indicated;
- the underlying data are to be described in the text box.

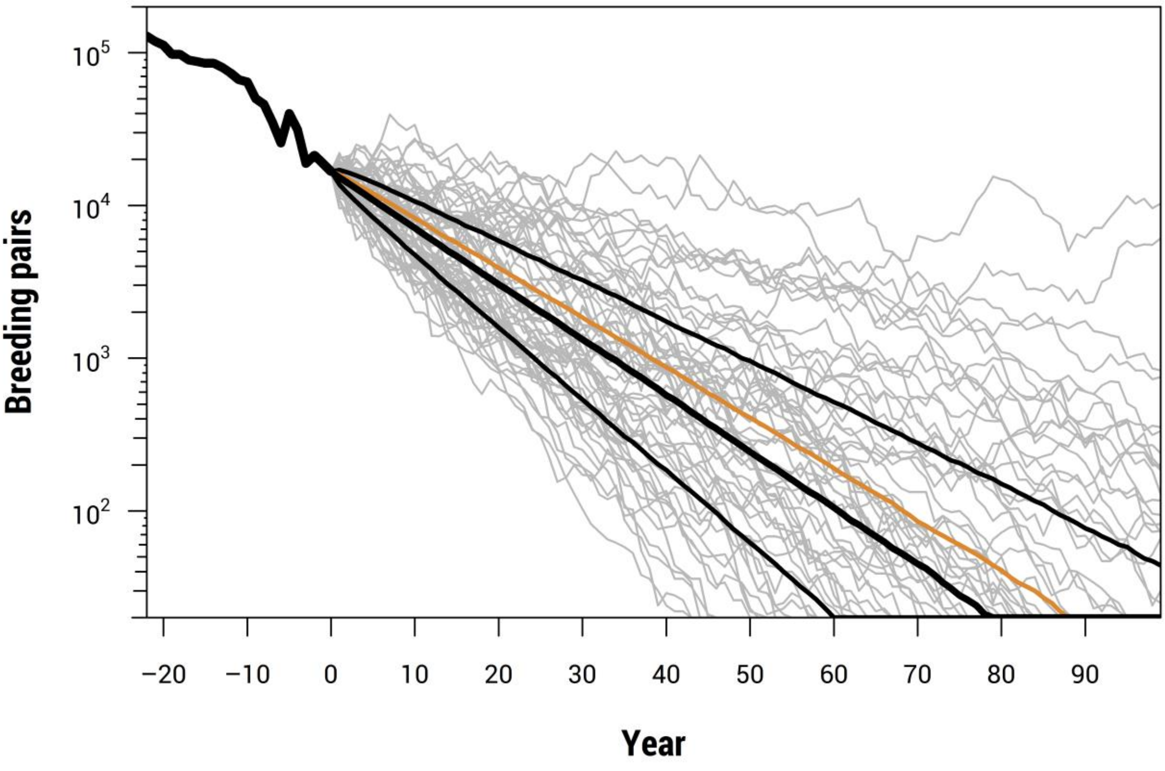

Figure 8: Example of a population viability analysis. Observed population numbers up to 2010 (negative years) and simulated numbers thereafter (positive years). Thin grey lines show some examples of simulated future trajectories. The three black lines show the quartiles (lower, median, upper) of all simulated trajectories; the orange line shows the 60th percentile. Lifetime is equivalent to the number of years until quasi-extinction, i.e. until the population crosses the quasi-extinction threshold (which was here set to 20 breeding pairs). The population is estimated to go extinct within 60 to 112 years (lower/upper quartile), with a median lifetime of 79 years and a 60th percentile of 88 years. Please note that the y-axis is on the logarithmic scale. The example is one population of *Rissa tridactyla*. (Source: Sandvik et al. 2014, modified)

5.1.2. Criterion B: expansion speed

> **[B] The higher the expansion speed of an alien species, the higher the species scores on the invasion axis. 'Expansion speed' here refers to the annual increase in the radius of the area of occupancy (estimated under the assumption of a circular area). The threshold values are defined as 50, 160 and 500 metres per year, respectively (Table 5).**

Expansion of a species is to be understood as the *number of new occurrences per time interval*, where 'occurrences' are colonised 2 km × 2 km grid cells (see section 2.7.3.). Expansion, as it is defined here, is thus a measure of *how fast the occurrences of a species increase in Norwegian nature*. That implies that expansion comprises *any form of movement or spread of the species*, including

- active natural dispersal (i.e., locomotion, migration),
- passive natural dispersal (by wind, water, animals etc.),
- anthropogenic displacement (intentional or otherwise),
- separate reintroductions (intentional or otherwise).

This entails that expansion speed is not normally identical with narrow-sense dispersal speed. Whenever anthropogenic transport (including reintroductions) is a significant factor, for example, expansion can be substantially faster than natural dispersal due to seed dispersal, migration etc. On the other hand, expansion may be far slower than estimates of the maximum dispersal distance per year, when the latter does not take account of establishment success.

Expansion speed is measured as a *change in radius*, i.e. in *metres per year*. The change in area of occupancy (AOO) is thus converted into a change in radius. This can be illustrated by imagining that the total area of occupancy of the species in Norway is transformed into one circular area, so that expansion speed corresponds to the yearly increase of this circle's radius. (The rationale for choosing the increase in radius rather than area, is that the latter is not independent of the current area; see Appendix II for further details.)

The threshold values for criterion B are given in Table 5 (cf. Figure 9).

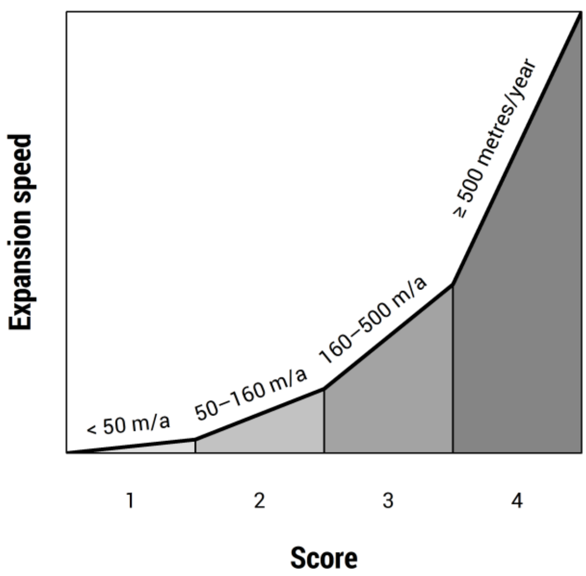

Figure 9: Illustration of criterion B. Expansion speed, defined as the annual rate at which the area of occupancy increases, is the basis for the score due to this criterion.

Estimation methods

Expansion speed may be estimated in several different ways, utilising observations from Norway or from abroad (or, if necessary and possible, from a closely related species). Three methods are supported by the AlienSpeciesDatabase. Which of these is used depends on whether the data available consist of

(a) a spatio-temporal dataset of reliable observations of the species over at least ten years;
(b) published data on the dispersal rate of the species (from Norway or elsewhere) in addition to an estimate of the number of source localities from which the species spreads in Norway; or
(c) an estimate of the increase in the number of occurrences during the latest year.

The methods are explained in detail below. When using method (b) or (c), one should report the highest realistic value measured, estimated or observed. (This may be better than for instance reporting the maximum value; see Appendix II).

(a) Spatio-temporal datasets of observations

If a reliable geo-referenced dataset of observations is available, these data can be used to estimate expansion speed (including uncertainty, i.e. interquartile range). This requires ten or preferable more years of data, where the year and coordinates are reported for each observation. One possible source of such datasets in Norway is the Species Map Service (http://artskart.artsdatabanken.no). Data can be downloaded directly from this service (choose a species → make any selections necessary → click the tab 'ObjectInfo' → click the button 'Export data to Excel').

An **R** script performing the calculations required is available at the URL http://www.evol.no/hanno/17/expand.htm. The website provides instructions on the use of the script.

NB! *The estimate of expansion speed is affected by the dark figure of the area of occupancy*. Therefore, the estimate can be improved considerably by providing an expert judgement of this dark figure. Please note, however, that *the dark figure of the area of occupancy is usually much lower than the dark figure of the number of localities*.

If this method is used in assessing criterion B in the AlienSpeciesDatabase,

- the result is to be provided in terms of the median expansion speed including quartiles;
- the time series used is to be uploaded (on uploading data, cf. section 1.4.).

(b) Published data on dispersal rate

If the dispersal rate of the species (or of a comparable species) has been estimated previously, this estimate might be used in the current context. However, it is essential to recall that *expansion speed is not the same as dispersal rate*. Published estimates must only be used if they describe the *velocity of an invasion front* (which entails that the area behind the front is actually colonised). Maximum dispersal distances of single individuals per year must not be used, for example.

Furthermore, published estimates of dispersal rates are usually based on natural dispersal only (migration, wind dispersal etc.). If the occurrences in Norway increase for other reasons, too (such as repeated anthropogenic introductions), this has to be taken into account. Therefore, the dispersal rate provided has to be supplemented by an estimate of the number of 'source populations' in Norway as of 2016, i.e. of the number of occurrences that function (or have functioned) as starting points of further dispersal.

If this method is used in assessing criterion B in the AlienSpeciesDatabase,

- the published value of dispersal rate is to be provided, preferable including uncertainty;
- an estimate of the number of localities that function as 'source populations' is to be provided;
- the reference to the publication and a description of its assumptions is to be provided.

(c) Estimated increase in AOO during the latest year

In the absence of the data required to use the above methods, the increase in AOO may be estimated as a recent average of the annual increase in the AOO (or in the number of occurrences). 'Recent average' here refers to a value that is representative of the increase during later years.

If this method is used in assessing criterion B in the AlienSpeciesDatabase,

- the area, *including dark figures*, by which the AOO increased during the last year is to be provided;
- the underlying assumptions and data used are to be described in the text box.

5.1.3. Criterion C: colonisation of nature types

A summary of the information about colonised nature types will be displayed in this panel. This information can only be modified through the 'Nature Types' tab (see chapter 4).

Table 7: Definitions of key terms used to describe ecological effects. Effects must be documented in Norway; or be documented elsewhere (or for a closely related species) *and* be likely to occur in Norway within 50 years. (AOO = area of occupancy; EOO = extent of occurrence)

Term	Definition
Species	
Threatened	species that is listed as vulnerable (VU), endangered (EN) or critically endangered (CR) according to the *Norwegian Red List for species 2015* (Henriksen and Hilmo 2015)
Keystone species	species that, despite being relatively rare* (in terms of biomass), can have a large effect on the abundance, distribution *or* diversity of other species (based on Power et al. 1996; for applications of this definition, see Libralato et al. 2006, Valls et al. 2015)
Geographical extent of interaction	
Local	effect that affects (*and* that most likely will remain constrained to) *less than* 5% of the population size *and* AOO *and* EOO of any native species
Large-scale	effect that affects (*or* will affect) *at least* 5% of the population size *or* AOO *or* EOO of any native species
Strength of interaction	
Weak	interaction that will *not* have at least moderate negative consequences on the population size of native species
Moderate	interaction that results (*or* will result) in a reduction of *at least* 15% in the population size of *at least* 1 native subpopulation over a 10-year period, but *without* displacing any native species (a population decline of 15% per decade corresponds to a reduction in carrying capacity *K* of 15% per decade or in the annual multiplicative growth rate λ of 2%)
Displacement	reduction of the AOO *or* EOO by *at least* 1% through interactions with an alien species

* Please note that common species do not fulfil this specific definition of keystone species. The rationale is that common species cannot go extinct as rapidly as threatened or rare species.

5.2. Ecological effect

The ecological effects of alien species comprise effects on native species and effects on nature types. Species that have been established with a stably reproducing population before 1800, are in this context regarded as native (see section 2.2.). Only negative effects are included in the assessment; neutral and positive effects are disregarded (see section 2.8.). The criteria on the effect axis (D–I) make use of a couple of key terms that are explained in Table 7 (and italicised in the criterion descriptions).

5.2.1. Time frame for ecological effects

As far as ecological effects are concerned, assessments are not only to take account of historical and current effects, but also of effects that, based on documented evidence, can be expected to occur in the future. The time frame for the assessment of ecological effects is set to *50 years or five generations* (whichever time period is longest), but not more than 300 years, into the future.

The prediction of future effects is necessarily more uncertain than the description of current effects. However, future effects are only to be included when it can be documented or substantiated (e.g., using evidence from other countries or from closely related species) that they are likely to occur. Such predictable effects include:

- the expansion of the area of occupancy and/or extent of occurrence of the species (and, thereby, the possible colonisation of nature types that up till now are unaffected);
- age dependent, density dependent or frequency dependent effects (effects that have not yet been observed in Norway *because the species has not been here for a sufficiently long time*, but that are documented elsewhere and transferable to Norwegian bioclimatic conditions);
- effects that become more likely under a changed climate (effects that have not yet been observed in Norway *because the climatic conditions have prevented them from occurring*, but that are documented in countries with a climate comparable to the one Norway may get in the future).

For climate projections for Norway, see Table 3 (p. 29) and klimaservicesenteret.no.

5.2.2. Criteria D and E: effects on native species

Effects on native species, meaning *negative interactions with native species*, includes mainly competition with, herbivory, predation of, and parasitism on native species, but also allelopathy and indirect effects (e.g., so-called apparent competition or trophic cascades; White et al. 2006). The *strength* of interactions is described as weak, moderate or displacement; the *geographic extent* of the interactions is described as local or large-scale. These key terms are defined in Table 7. An effect is described as *unlikely* if the alien species does not interact with any native species (this option is only possible for threatened or keystone species). The criteria are defined as follows:

[D] The stronger the negative ecological interactions that an alien species has with *threatened* or *keystone species*, the higher it scores on the effect axis. A *weak* interaction is scored as 3; an interaction that is at least *moderate*, is scored as 4; if *weak* or *moderate* interactions are *local* only, the score is reduced by one (Table 8).

[E] The stronger the negative ecological interactions that an alien species has with other species (that are neither *threatened* nor *keystone*), the higher it scores on the effect axis. A *moderate* interaction is scored as 2; *displacement* is scored as 4; if *moderate* interactions or *displacements* are *local* only, the score is reduced by one (Table 8).

In the AlienSpeciesDatabase, effects on native species are documented in the following manner:

- Interactions with specific native species are indicated by adding the species affected to a list (by writing the beginning of the name in the search box, and choosing the intended species). If the alien species interacts with many native species, it is sufficient to add the species that are most strongly affected. If there are threatened species (VU, EN, CR) among the species affected, these have to be listed. Additional information may be provided in the text box.
- Effects on entire societies of species are indicated by choosing the nature type affected. (The drop-down list only contains nature types that have been registered in the tab 'Nature types').
- For each interaction, the following information is to be provided:
    - for specific species: check off whether the native species is considered a keystone species,
    - for nature types: check off whether threatened or keystone species are affected,
    - the strength of the interaction (weak/moderate/displacement as defined in Table 7),
    - check off whether the interaction is local (as defined in Table 7),
    - type of interaction (herbivory, predation, parasitism, competition for space, competition for food, allelopathy, others [e.g., indirect ecological interactions]),
    - check off whether the effect is a distance effect or due to escaped individuals (section 2.6.3.),
    - check off whether the effect is documented (rather than assumed as likely),
    - check off whether the documentation is from Norway (rather than abroad).
- Finally, the uncertainty is indicated, separately for criteria D and E, by checking off (☑) all scores that, based on Table 8, have an expected likelihood of more than 25% (cf. section 5.0.).

5.2.3. Criteria F and G: effects on nature types

A summary of the information about effects on nature types will be displayed in this panel. This information can only be modified through the 'Nature Types' tab (see chapter 4).

Table 8: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria D–G. Key terms are defined in Table 7; Table 9 contains criteria H/I. All criteria are to be evaluated, and the highest score obtained by any of the criteria D–I determines the placement along the effect axis.

Criterion	**D**	**E**	**F**	**G**
	Documented or likely effect within 50 years on			
	native species		nature types	
Score for ecological effect	threatened or keystone	other	threatened or rare	other
1 (no known effect)	unlikely	weak	unlikely	< 5%
2 (minor effect)	weak *AND* local	moderate*	> 0%	≥ 5%
3 (medium effect)	weak *AND* large-scale	local displacement	≥ 2%	≥ 10%
4 (major effect)	moderate* *OR* displacement	large-scale displacement	≥ 5%	≥ 20%

* If the effect is moderate *and local*, the score is to be *reduced by one*.

5.2.4. Criterion H: transfer of genetic material

[H] The larger the likelihood or consequence of an alien species genetically contaminating native species, the higher the species scores on the effect axis. 'Genetic contamination' here refers to introgression, i.e. a transfer of genetic material from the gene pool of the alien species to the gene pool of at least one native species. Documented or likely introgression is scored as 3; if the recipient native species is *threatened* or a *keystone species*, the score is increased by one; if the introgression only has *local* effects, the score is reduced by one (Table 9).

Please note that the transfer of genetic material to the gene pool of a native species presupposes introgression. Mere hybridisation does not fulfil this definition. Genes are considered transferred when there is backcrossing between hybrids and the native population.

In the AlienSpeciesDatabase, transfer of genetic material is documented in the following manner:

- Native species affected are specified by adding them to a list (by writing the beginning of the name in the search box, and choosing the intended species). If many native species are affected, it is sufficient to add the species that are most strongly affected. If there are threatened species (VU, EN, CR) among the species affected, these have to be listed. For each native species chosen, the following information is to be provided:
  - check off whether the native species is considered a keystone species,
  - check off whether the interaction is local (as defined in Table 7),
  - check off whether the effect is a distance effect or due to escaped individuals (section 2.6.3.),
  - check off whether the effect is documented (rather than assumed as likely),
  - check off whether the documentation is from Norway (rather than abroad).
- Finally, the uncertainty is indicated by checking off (☑) all scores that, based on Table 9, have an expected likelihood of more than 25% (cf. section 5.0.).

NB! *If a taxon below the species level is assessed, and introgression happens to native taxa within the same species only (*intra*specific hybridisation), it cannot necessarily be taken for granted that the intro-*

Table 9: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria H and I. Key terms are defined in Table 7; Table 8 contains criteria D–G. All criteria are to be evaluated, and the highest score obtained by any of the criteria D–I determines the placement along the effect axis.

Criterion	H	I
	Documented or likely transmission of	
Score for ecological effect	genetic material	parasites or pathogens**
1 (no known effect)	unlikely	unlikely
2 (minor effect)	locally to native species	existing parasites to existing hosts such that prevalence increases*
3 (medium effect)	large-scale to native species	existing parasites to novel hosts*
4 (major effect)	to threatened or keystone species*	existing parasites to novel threatened or keystone hosts* *OR* of alien parasites

* If the effect is merely *local*, the score is to be *reduced by one*.

** The score of the host must not exceed the score that the parasite obtains for ecological effect.

gression has (or will have) a negative effect on the native taxa. If it can be documented or substantiated that this intraspecific hybridisation does *not* have negative effects (e.g., because it counteracts inbreeding depression), this should be explained in the text box, and the *score should be set to 1* (by emptying the list of affected species. This exception does *not* apply to *inter*specific introgression (across species).

5.2.5. Criterion I: transmission of parasites or pathogens

> **[I] The criterion is used if it is documented or likely that an alien species might act as a vector for parasites (including pathogens such as bacteria or viruses) to native hosts. If this transmission entails an increased prevalence of existing parasites to a native species that already functions as a host for the same parasite, the effect is scored as 2. If transmission is to a native species that has not been a host for this parasite, the vector is scored as 3. The score is increased to 4 under two conditions: if the alien species acts as a vector for a parasite that is itself alien to Norway; or if at least one of the novel native hosts is a threatened or a keystone species. If the transmission of existing parasites remains locally restricted, the score is reduced by one. In any case, the score of the host is constrained upwards to the maximum score for ecological effect that is (or would have been) assigned to the parasite transmitted (Table 9).**

Criterion I is meant for assessing the *host* species of parasites and *not* for assessing parasite species. The ecological effect of parasites is to be assessed using criteria D–H. Note that a host cannot get a higher score according to criterion I than its parasite has (or would have) got according to criteria D–H. For example, if the only effect of a parasite is a moderate interaction with a native species of least concern (i.e., score 2 according to criterion F), its host cannot receive a higher score than 2 according to criterion I (even if the parasite is alien to Norway).

In the AlienSpeciesDatabase, the transmission of parasites or pathogens is documented in the following manner:

- Native species affected are specified by adding them to a list (by writing the beginning of the name in the search box, and choosing the intended species). If many native species are affected, it is sufficient to add the species that are most strongly affected. If there are threatened species (VU, EN, CR) among the species affected, these have to be listed. For each native species chosen, the following information is to be provided:
    - check off whether the native host species is considered a keystone species,
    - fill in the scientific name of the parasite,
    - fill in the ecological effect of the parasite (i.e., its highest score according to criteria D–H),
    - check off whether the infection is local (as defined in Table 7),
    - check off whether the parasite is alien to Norway (according to the definition in section 2.1. and the delimitations in section 2.6.),
    - check off whether the parasite is novel to the native host species,
    - check off whether the effect is documented (rather than assumed as likely),
    - check off whether the documentation is from Norway (rather than abroad).
- Finally, the uncertainty is indicated by checking off (☑) all scores that, based on Table 9, have an expected likelihood of more than 25% (cf. section 5.0.).

5.3. Geographical variation

Norway is a long country, exhibiting a huge variation in bioclimatic and other environmental variables (cf. Table 2). Any species with a certain extent of occurrence will thus experience varying environmental conditions and – in response to these – itself display varying characteristics. Cases where this variation would have resulted in different impact categories, are to be visualised.

Irrespective of the geographic variation, it is the strongest impact on Norwegian nature that determines the final impact category, and whether the species is black-listed. The geographic variation will be visualised to users and the public as *supplementary* information in the AlienSpeciesDatabase.

It is up to the expert groups to decide whether the geographic variation in the species characteristics is large and relevant enough to deserve a description. If a species would have received different impact categories (NK/LO/PH/HI/SE) in different parts of its (potential) area of occupancy, this may be used as an indication that the geographic variation ought to be described. If any of the following questions is answered in the positive (using check boxes), further information should be provided in the text box:

- Is the species's ability to reproduce or disperse restricted to certain climatic zones or sections?
- Are the ecological effects of the species restricted to certain climatic zones or sections?
- Are the ecological effects of the species restricted to some specific nature type(s)?
- Is the only ecological effect of the species its interaction with a native species that has a very restricted distribution?

5.4. Climate effects

On this tab, a summary can be provided of the role that the projected climatic changes play for the risk assessment of the species. As described above, projected climatic changes should enter into the risk assessment as such:

- The description of the potential distribution of the species should be based on the most likely situation 50 years from now, which entails a changed climate (cf. section 3.5.).
- The assessment of the ecological effects of the species likewise has a time frame of 50 years (or five generations) ahead, which includes effects that are not yet observed in Norway, but are likely to occur under a changed climate (cf. section 5.2.1.).

For these reasons, the tab is not expected to contain novel information, but merely a summary. The tab contains two check boxes, one for each axis, indicating whether the risk scores would have differed in the absence of climate change:

- Is the score for invasion potential affected by climatic changes?
- Is the score for ecological effect affected by climatic changes?

In the text box, a short description of the significance of climate change should be provided, where relevant. If the effect of climate is especially uncertain, or if the predictions of future expansion and/or effects are crucially dependent on the climate scenario chosen (e.g., RCP4.5 versus RCP8.5, see Table 3 on page 29 and Hanssen-Bauer et al. 2015), this ought to be described here. This might for instance be the case if the species is not able to disperse under current conditions, but will have a huge dispersal potential under warmer conditions (especially when it is uncertain whether this temperature threshold will be crossed by 2066).

5.5. Documentation

The background for each assessment is to be summarised in the 'Documentation' tab. This text will be made available through the public interface of the AlienSpeciesDatabase when the assessments are published. To many users, this is by far the most important information. The text should be precise, but at the same time understandable for laypeople. That is why the text should use complete sentence and have a high readability. The reader ought to understand, after having read this text, why the species has been assigned to its impact category. Relevant literature should be cited in the text (while the references are to be uploaded on the 'References' tab).

In order to standardise the format of documentations, the tab is divided into six text boxes:

- *Species description:* taxonomy, status according to the delimitations (e.g., door knocker, regionally alien species), area of origin, lifestyle.
- *Distribution in Norway:* when and how did the species arrive in Norway, distribution history, current area of occupancy and extent of occurrence. This text is pasted from the text box 'Distribution history in Norway' (cf. section 3.5.), but can be edited (and should be double-checked) here, too.
- *Pathways:* description of the pathways of introduction and spread, and of the species characteristics that contribute to spread (e.g., morphology, behaviour, ecology).
- *Invasion potential:* description of the criteria that determine the score on the invasion axis (including the relevant knowledge base and the factors contributing to uncertainty).
- *Ecological effect:* description of the criteria that determine the score on the effect axis (including the relevant knowledge base and the factors contributing to uncertainty).
- *Conclusion:* a short summary, including the impact category (1–3 sentences).

Where available, texts from the AlienSpeciesDatabase 2012 will be transferred to the Conclusion text box. If so, the text needs to be redistributed over the five other text boxes and updated, where necessary.

6. List of changes

Changes from version 2 (2012) to version 3 (2016)

In order to facilitate comparisons with the 2012 assessments, an overview of the changes in method and criteria is provided. **NB!** *This list is not necessarily exhaustive.*

Definitions and delimitations
Selected *regionally alien* species and *taxa below the species level* have been included in the risk assessments. The term *native species* has received an explicit definition (which is *not* 'all species that are not alien', see section 2.2.). The definitions of *establishment*, *Norwegian nature*, *production species* and *production area* are new (or changed).

Set of criteria
The basic structure of the set of criteria is unchanged, although some of the criteria have been updated. The changes entail that the set of criteria has now become fully quantitative (cf. Appendix III). A detailed overview and explanation of the changes is available in Appendix II.

- Criterion A: the threshold values have been adjusted, now equalling the ones of Red List criterion E.
- Criterion B: expansion speed has received an entirely new definition, which replaces B_1–B_3.
- A/B interaction: at low expansion speeds, the importance of criterion A has been downweighted.
- Criterion D: local effects have been downweighted; all threshold values are quantitative.
- Criterion E: local effects have been downweighted; all threshold values are quantitative.
- Criterion F: state changes that affect < 2% of the area of a nature type, are defined as minor.
- Criterion H: local effects have been downweighted.
- Criterion I: the score has been constrained to the maximum effect of the parasite.

Nature types
Definitions of nature types (natural systems) and the quantification of effects upon these follow NiN 2 (with the exception of red-listed nature types, which still follow NiN 1). The term 'artificial ground' is not used any more, and has been replaced by 'heavily modified nature'. Heavily modified nature is taken into account when assessing criteria A/B, D/E or H/I, but is disregarded when assessing criteria C, F and G. For details, see Appendix V.

Uncertainty
Rather than treating uncertainty as an either/or question, uncertainty is now quantified (as far as possible) in terms of lower and upper quartiles for all estimates. Dark figures, too, have to be provided with uncertainty. Definitions, explanations and examples are provided in sections 2.9.1. and 5.0.

Geographical variation
Cases where a species displays a huge amount of geographic variation in its characteristics are to be visualised. This applies to species that would have received a lower impact category in parts of their area of occupancy (see section 5.3.).

AlienSpeciesDatabase

The *AlienSpeciesDatabase* has received an improved and more user-friendly interface. Scores are now calculated automatically, based on the information that experts provide about the species assessed. This ensures coherence between impact categories and the documentation. Uncertainty is still to be indicated manually (in most cases).

The classification of *pathways* of introduction (termed 'vector' in 2012) has been updated so as to follow international guidelines (cf. Appendix IV). The distinction between entry, introduction and spread are made more explicit.

All information about *nature types* (including species information and assessment of criteria C, F and G) are collected in one tab.

Effects of climate change on the assessment result is summarised in a separate tab.

Changes from version 3.1 (June 2016) to version 3.3 (August 2016)

The following changes were carried out after version 3.1 had been released:

- The definition of door knockers was made more concise (section 2.5.).
- The definition of occurrence was made more concise (section 2.7.3.).
- The definition of original distribution was improved (section 3.2.).
- Dark figures in AOO are to be included when assessing criterion C (chapter 4.).

7. Appendices

I. Set of criteria for the Generic Ecological Impact Assessment of Alien Species

GEIAA, version 3

**Hanno Sandvik (Centre for Biodiversity Dynamics,
Norwegian University of Science and Technology)**

This set of criteria for the Generic Ecological Impact Assessment of Alien Species (GEIAA) is based on a revision of the method described by Sandvik et al. (2013) and Sandvik (2012).

The guiding principles during the development and revision of the set of criteria, were that the method be (i) *quantitative* and (ii) *generic*, and that (iii) the risk categories capture the *ecological impact* of alien species on [Norwegian] nature. The set of criteria now uses numerically defined threshold values only, as they are known from the Red List (IUCN 2012, Henriksen and Hilmo 2015). Such quantitative sets of criteria have a number of advantages over qualitative sets of criteria (see Appendix III). The most important advantage is that the subjectivity, which always enters into expert judgement, is reduced. The result thus becomes more transparent, repeatable and testable. It is straightforward for decision makers, interest groups or other experts to check the basis of the impact category of a given species. Furthermore, quantitative assessments facilitate the inclusion of novel knowledge and the correction of errors, because impact categories are not based on overall assessments, but on separate criteria that can be updated independently.

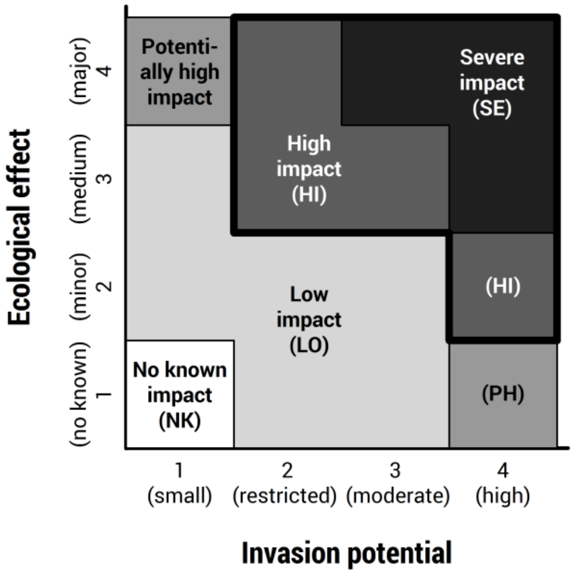

Figure I-1: Categories assigned to alien species mirror their impact. The system operates with five impact categories, depending on invasion potential (Table I-1) and ecological effect (Tables I-3 and I-4) of alien species. The Black List consists of species with high and severe impacts.

The main difference from many other sets of criteria for impact assessment of alien species is that GEIAA's criteria are generic, i.e. they can be used for all groups of organisms (*taxa*). The impact categories are therefore comparable for fungi, insects, echinoderms etc.

The ecological impact that alien species have on native nature is proportional to the area colonised, to the density achieved within that area, and to the per-capita effect of the species upon nature (Parker et al. 1999). As the exact area colonised is often unknown, especially when colonisation is not complete, area can be replaced with the species' invasion potential. Population density and per-capita effect can be integrated into a measure of per-locality ecological effect. The expected ecological *impact* can thus be defined as the product of *invasion potential* and *ecological effect*. As these two factors must be multiplied, and not added together, if the ecological impact is to be quantified, a species will have a small impact whenever one of the factors is small, regardless as to how large the other factor is. For this reason, the impact of alien species on nature can best be captured using a two-dimensional figure, where impact is indicated by the species' position along two axes – the invasion axis and the effect axis (Figure I-1).

The set of criteria for assigning alien species to impact categories comprises nine criteria. Three of these determine the species' invasion potential, and six the ecological effect. Species are evaluated against all criteria. A species's position along each axis is determined by those criteria that result in the highest score. The species is then placed into one of the five impact categories:

- severe impact (**SE**),
- high impact (**HI**),
- potentially high impact (**PH**),
- low impact (**LO**) or
- no known impact (**NK**).

The following sections provide a detailed description of the criteria. The corresponding threshold values can be found in Tables I-1, I-3 and I-4.

Invasion axis

Alien species are classified along the invasion axis depending upon their invasion potential. Invasion processes can be split into two phases, which form the basis for one criterion each: establishment and expansion (Table I-1). A third criterion relates to the proportion of nature types that can be colonised.

Criterion A: median population lifetime

> **[A] The higher the median population lifetime of an alien species in Norway, the higher the species scores on the invasion axis. 'Median population lifetime' refers to the time when it is 50% likely that the population in Norway has gone extinct. The threshold values are defined as 10, 60 and 650 years, respectively (Table I-1).**

The median population lifetime is a measure for the viability of a species, and is readily converted into likelihood of extinction. Therefore, criterion A can be considered as a mirrored version of the Red List criterion E (IUCN 2012, Henriksen and Hilmo 2015): the larger an alien species's likelihood of extinction (or the shorter its population lifetime in Norway), the less viable it is. The threshold values for this criterion are equal to the ones used in the Red List to distinguish between critically endangered, endangered, vulnerable and near threatened species.

Population lifetime can be large for a diversity of reasons, such as a large population size, a high population growth rate and/or a low demographic or environmental variance. The advantage of using median population lifetime as a criterion is that it is comparable across a wide range of species with very different lifestyles and demographies / life histories.

Criterion B: expansion speed

> **[B] The higher the expansion speed of an alien species, the higher the species scores on the invasion axis. 'Expansion speed' here refers to the annual increase in the radius of the area of occupancy (estimated under the assumption of a circular area). The threshold values are defined as 50, 160 and 500 metres per year, respectively (Table I-1).**

Expansion comprises *any* form of movement or spread of the species, irrespective of the mechanism or pathways involved. Expansion thus does not only include 'natural' movements by active locomotion or passive dispersal (e.g., by wind, water or animals), but also intentional or unintentional anthropogenic displacement, e.g. by transport within the country or separate re-introductions into the country. Expansion thus becomes identical to an increase in the species's area of occupancy (AOO).

The rationale behind measuring expansion speed in metres per year is that this unit is independent of the expansion history, making it an ideal measure of invasion propensity. The estimation of expansion speed as an increase of the radius does not depend on the AAO actually being circular, it is merely a means of standardising expansion speed.

Criterion C: colonisation of nature types

> **[C] The larger the area of a nature type colonised by an alien species, the higher the species scores on the invasion axis. 'Area colonised' here refers to the proportion of the AOO of the nature type(s) affected that will contain occurrences of the species within 50 years. This proportion is to be assessed separately for the nature types affected, and the largest proportion determines the score. The threshold values are defined as 5%, 10% and 20%, respectively (Table I-1).**

This criterion measures the invasion potential separately for the nature types concerned. It is included to take account of the fact that certain nature types can become colonised by an alien species which evades criteria A and B. This might for instance be the case when an alien species is specialised on a

Table I-1: Criteria, scores and threshold values for the classification of the invasion potential of alien species. [Due to additional conditions (see notes below), criteria A and B are dependent on each other.]

Criterion Score for invasion potential	**A** Median population lifetime	**B** Expansion speed	**C** Colonisation of nature types
1 (small invasion potential)	< 10 years	< 50 m/a	< 5%
2 (restricted invasion potential)	≥ 10 years [*AND* **B** ≥ **2**]*	≥ 50 m/a	≥ 5%
3 (moderate invasion potential)	≥ 60 years [*AND* **B** ≥ **2**]*	≥ 160 m/a [*AND* **A** ≥ **2**]*	≥ 10%
4 (high invasion potential)	≥ 650 years [*AND* **B** ≥ **3**]**	≥ 500 m/a [*AND* **A** ≥ **3**]*	≥ 20%

* If the additional condition is *not* fulfilled, the score is to be *reduced by one*.

** If the additional condition is *not* fulfilled, the score is defined as the *score of criterion B increased by one*.

NB! *The additional conditions do* not *apply to species that have distance effects or escaped individuals.*

relatively uncommon nature type. Such a species may pose a threat to this specific nature type, even when its population lifetime and expansion speed are not known to be especially high.

The definition and delimitation of nature types follows *Nature in Norway* (Halvorsen et al. 2015). Heavily modified nature is *not* to be taken into account when assessing criterion C.

Combination of criteria A and B

The placement of an alien species along the invasion axis is determined by scores that the species receives according to criteria A to C. In reality, invasion potential is the product, rather than the sum, of viability and expansion rate. An alien species that is well established within a restricted area and that shows no sign of expanding further, has a small invasion potential. The same applies for alien species that experience numerous and regular introductions across the country, whilst the individual subpopulations are not viable. Therefore, a species cannot achieve high scores on criteria A and B unless the score of the other criterion also exceeds a certain threshold (see the footnotes to Table I-1). This takes account of the fact that a species cannot have any significant invasion potential if it *only* has a high viability or *only* has a high expansion rate, whereas the other category is low.

Criterion C does not interfere with A and B, as its intention is to take account of invasions of relatively uncommon nature types. A threat towards nature types alone can therefore result in a high score along the invasion axis, even without the 'help' from criterion A or B.

Effect axis

Alien species are classified along the effect axis depending upon their negative effects upon nature. The six criteria measure ecological and genetic effects on native species as well as effects on nature types.

The placement of an alien species along the effect access is determined by the highest score assigned to the species using criteria D to I. This is better than summing the six effects, because a sum would underestimate the effect of a species that scores very high in one criterion, yet low in the others (Makowski and Mittinty 2010).

All effects are considered over a 50-year perspective. This means that not only current effects are assessed, but also effects that are likely to occur within the next 50 years. Such future effects must be based upon documented knowledge on the alien species's biology and upon projections of environmental change. For species with generation times of more than 10 years, a time horizon of 5 generations is used instead, but not more than 300 years.

The effect axis is limited to identifying ecological effects. Anthropocentric effects of alien species, such as direct or indirect effects upon human health, economy or aesthetics, are deliberately excluded. This is because the aim of the set of criteria is a purely ecological impact assessment. Where knowledge on anthropocentric effects is available, this information is included in the species information, but is not used in the impact assessment itself.

Some key terms are italicised in the following criteria definitions. These are explained in Table I-2.

Criteria D and E: ecological interactions with native species

Interactions with native species include competition with, herbivory or predation upon and parasitism of native species, but may also include allelopathy or indirect effects (e.g., so-called apparent competition or trophic cascades; White et al. 2006). Only negative effects are taken into account; neutral and positive interactions (e.g. facilitation; Bruno et al. 2003) are not considered. Ecological effects can be quantified rather accurately by measuring the reduction in the population growth rate, carrying capacity, area of occupancy (AOO) or extent of occurrence (EOO) of native species, caused by an alien species (see Table I-2 for the definitions used here; cf. Laksa and Wootton 1998). Ecological interactions with native species are measured by two criteria:

> **[D] The stronger the negative ecological interactions that an alien species has with *threatened* or *keystone species*, the higher it scores on the effect axis. A *weak* interaction is scored as 3; an interaction that is at least *moderate*, is scored as 4; if *weak* or *moderate* interactions are *local* only, the score is reduced by one (Tables I-2 and I-3).**

> **[E] The stronger the negative ecological interactions that an alien species has with other species (that are neither *threatened* nor *keystone*), the higher it scores on the effect axis. A *moderate* interaction is scored as 2; *displacement* is scored as 4; if *moderate* interactions or *displacements* are *local* only, the score is reduced by one (Tables I-2 and I-3).**

Table I-2: Definitions of key terms used to describe ecological effects. Effects must be documented in Norway; or be documented elsewhere (or for a closely related species) and be likely to occur in Norway within 50 years. (AOO = area of occupancy; EOO = extent of occurrence)

Term	Definition
Displacement	reduction of the AOO *or* EOO by *at least* 1% through interactions with an alien species
Keystone species	species that, despite being relatively rare (in terms of biomass), can have a large effect on the abundance, distribution *or* diversity of other species (based on Power et al. 1996; for applications of this definition, see Libralato et al. 2006, Valls et al. 2015)
Large-scale	effect that affects (or will affect) *at least* 5% of the population size *or* AOO *or* EOO of a native species
Local	effect that affects (*and* that most likely will remain constrained to) *less than* 5% of the population size *and* AOO *and* EOO of a native species
Moderate	interaction that results (or will result) in a reduction of *at least* 15% in the population size of *at least* 1 native subpopulation over a 10-year period, but *without* displacing any native species (a population decline of 15% per decade corresponds to a reduction in carrying capacity *K* of 15% per decade or in the annual multiplicative growth rate λ of 2%)
Rare	nature type that is near threatened (NT) because of a low number of occurrences (i.e., according to criterion 2 or 3 for the red-listing of nature types; Lindgaard and Henriksen 2011)
Substantial	state change in a nature type that corresponds to at least one well-defined (countable) level *or* to more than one third of the levels defined for the environmental variable concerned (or to that number of levels more than the state change would have been in the absence of the species)
Threatened	species or nature type that is listed as vulnerable (VU), endangered (EN) or critically endangered (CR) according to the *Norwegian Red List for species 2015* (Henriksen and Hilmo 2015) or the *Norwegian Red List for ecosystems and habitat types 2011* (Lindgaard and Henriksen 2011), respectively
Weak	interaction that will *not* have at least moderate negative consequences on the population size of native species

Criteria F and G: state changes in nature types

Alien species can also have ecological effects at the landscape level, e.g. by altering vegetation stratification, overgrowing an open landscape, thinning of a woodland or eutrophication of a water-body. These effects can be measured, in the nature types affected, as state changes in relevant environmental variables, i.e. as changes in the condition, state, species composition or spatial structure of nature types. (For the definition of nature types, environmental variables and their levels, see *Nature in Norway*; Halvorsen et al. 2015, 2016).

[F] The larger the area of *threatened* or *rare* nature types undergoing change due to an alien species, the higher the species scores on the effect axis. 'Change' here refers to a *substantial* state change in at least one environmental variable (see Table I-2). 'Area' here refers to the proportion of the AOO of the nature type(s) affected. This proportion is to be assessed separately for the nature types affected, and the largest proportion determines the score. The threshold values are defined as 0%, 2% and 5%, respectively (Table I-3).

[G] The larger the area of other nature types undergoing change due to an alien species, the higher the species scores on the effect axis. 'Other nature types' here refers to nature types that are neither *threatened* nor *rare* nor heavily modified. The remaining definitions follow criterion F. The threshold values are defined as 5%, 10% and 20%, respectively (Table I-3).

Table I-3: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria D–G. Key terms are defined in Table I-2; Table I-4 contains the remaining criteria of the effect axis. All criteria are to be evaluated, and the highest score obtained by any of the criteria D–I determines the placement along the effect axis.

Criterion	D	E	F	G
	Documented or likely effect within 50 years on			
	native species		nature types	
Score for ecological effect	threatened or keystone	other	threatened or rare	other
1 (no known effect)	unlikely	weak	unlikely	< 5%
2 (minor effect)	weak *AND* local	moderate*	> 0%	≥ 5%
3 (medium effect)	weak *AND* large-scale	local displacement	≥ 2%	≥ 10%
4 (major effect)	moderate* *OR* displacement	large-scale displacement	≥ 5%	≥ 20%

* If the effect is moderate *and local*, the score is to be *reduced by one*.

Criterion H: transfer of genetic material

[H] The larger the likelihood or consequence of an alien species genetically contaminating native species, the higher the species scores on the effect axis. 'Genetic contamination' here refers to introgression, i.e. a transfer of genetic material from the gene pool of the alien species to the gene pool of at least one native species (mere hybridisation without subsequent backcrossing does not fulfil this definition). Documented or likely introgression is scored as 3; if the recipient native species is *threatened* or a *keystone species*, the score is increased by one; if the introgression only has *local* effects, the score is reduced by one (Tables I-2 and I-4).

Criterion I: transmission of parasites and pathogens

[I] The criterion is used if it is documented or likely that an alien species might act as a vector for parasites (including pathogens such as bacteria or viruses) to native hosts. If this transmission entails an increased prevalence of existing parasites to a native species that already functions as a host for the same parasite, the effect is scored as 2. If transmission is to a native species that has not been a host for this parasite, the vector is scored as 3. The score is increased to 4 under two conditions: if the alien species acts as a vector for a parasite that is itself alien to Norway; or if at least one of the novel native hosts is a threatened or a keystone species. If the transmission of existing parasites remains locally restricted, the score is reduced by one. In any case, the score of the host is constrained upwards to the maximum score for ecological effect that is (or would have been) assigned to the parasite transmitted (Table I-2 and I-4).

Table I-4: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria H and I. Key terms are defined in Table I-2; Table I-3 contains the remaining criteria of the effect axis. All criteria are to be evaluated, and the highest score obtained by any of the criteria D–I determines the placement along the effect axis.

Criterion	**H**	**I**
Score for ecological effect	Documented or likely transmission of genetic material	Documented or likely transmission of parasites or pathogens**
1 (no known effect)	unlikely	unlikely
2 (minor effect)	locally to native species	existing parasites to existing hosts such that prevalence increases*
3 (medium effect)	large-scale to native species	existing parasites to novel hosts*
4 (major effect)	to threatened or keystone species*	existing parasites to novel threatened or keystone hosts* *OR* of alien parasites

* If the effect is merely *local*, the score is to be *reduced by one*.

** The score of the host must not exceed the score that the parasite obtains for ecological effect.

Impact categories

The four subcategories along each axis provide the basis for 16 possible combinations of invasion potential and ecological effects (Figure I-1). The position of a species in Figure I-1 illustrates the (risk of) impact that a species exerts on nature. The position determines, in turn, which of the five impact categories the species is placed in. Species in the two highest impact categories (SE and HI) are included on the Black List.

Alien species with a potentially high impact (PH) have at present little influence upon nature, but are placed in their own impact category because their influence can increase due to unforeseen changes. These changes might be evolutionary or ecological. Even though rapid evolutionary change has been documented in several alien species (Cox 2004, Lavergne and Molofsky 2007, Whitney and Gabler 2008), it cannot be predicted. The same applies to unexpected ecological interactions, especially indirect ones (White et al. 2006, Doak et al. 2008). The category PH is meant to account for and to highlight such unpredictability.

If the exact combination of subcategories is communicated, such information is added after the abbreviation: **HI:4,2** and **HI:2,3** signify two different high-impact species, where the first has a high invasion potential and minor effects, whereas the second has a restricted invasion potential and medium effects. This information will be particularly relevant for species with potentially high impact, where species with **PH:1,4** and **PH:4,1** will have very different properties. In addition, the criteria that form the basis of classification, may be indicated: For example, **HI:2(b),4(egi)** represents a species that has been classified as a having a high impact because it displaces native species, alters nature types, transmits parasites and has a limited expansion speed. Similarly, a species given as **H1:2(a),4(h)** falls under the same impact category based on hybridisation and the population lifetime.

The classification system for alien species does not operate with a category for data deficiency (as in ‘DD’ in the Red List). There are several reasons for this. First, uncertainty is a matter of degree, rather than an either–or question. It should therefore be included in the impact assessment, and not be excluded from it as a category in its own right. Secondly, data deficiency has opposite meanings for threatened and for alien species: if one has little or no documented knowledge about a species, this is often due to its rareness. All else being equal, this makes it more likely that the species is threatened with extinction, but also *less* likely that it is a problem species. When documentation about invasion potential or ecological effect is lacking, a species will be classified as having ‘no known impact’. This does not necessarily mean that the species will never affect nature, but merely that no knowledge is available that suggests this. Even though such an assessment may later be shown to have been erroneous and require a revision, it is unlikely that the species will present a high or severe impact, as in this case one would expect the availability of evidence of impacts in other countries.

II. Changes in the set of criteria 2012–2017

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The set of criteria used for risk assessments in 2012 was based on a peer-reviewed method (Sandvik et al. 2013), but had for practical reason to deviate in some points from the latter. The criteria actually used in assembling the alien species list 2012 (Gederaas et al. 2013) were described in a chapter of that publication (Sandvik 2013). Based on feedback from experts and users on one hand and additional method development on the other hand, the set of criteria has been revised during 2015 and 2016. The current version is included here as Appendix I.

The basic structure of the set of criteria has remained unchanged. Criterion B is the only criterion that received an entirely new definition (although fulfilling the same rationale). For some other criteria, the threshold values have been adjusted. This Appendix provides a detailed survey of these changes and explains their rationale. In Tables II-1, II-3 and II-4, changes are highlighted using orange font colour.

Criterion A: population lifetime

The intention of criterion A is to measure the long-term establishment potential of an alien species. As can be seen from Table 6 (page 36), establishment potential can be expressed by several equivalent quantities: the likelihood of extinction within *x* years (P_x), median lifetime ($\tilde{L}$) and expected lifetime ($\bar{L}$).* The main change concerning criterion A is that the threshold values were adjusted so that they are congruent to the ones used by Red List criterion E (IUCN 2012, Artsdatabanken 2014):

The threshold between score 1 and 2 is now identical to the threshold between critically endangered and endangered (P_{10} = 50%; $\tilde{L}$ = 10.0 years; $\bar{L}$ = 14.4 years); the threshold between score 2 and 3 is now identical to the threshold between endangered and vulnerable (P_{20} = 20%; $\tilde{L}$ = 62.1 years; $\bar{L}$ = 89.6 years); and the threshold between score 3 and 4 is now identical to the threshold between vulnerable and near threatened (P_{100} = 10%; $\tilde{L}$ = 658 years; $\bar{L}$ = 949 years).

The threshold values are now provided in terms of median lifetime rather than expected lifetime, mainly because this yielded 'rounder numbers' and because, statistically speaking, the median is somewhat more informative than the mean. By rounding the median lifetimes to the nearest 'round number' (within 5%), the threshold values were set to 10 years (no rounding needed), 60 years (rounded downwards by 3%) and 650 years (rounded downwards by 1%)

The new thresholds values deviated from the ones used in 2012 by 44% (from 6.9 to 10.0 years), 73% (from 34.7 to 60.0 years) and 6% (from 693.1 to 650.0 years), respectively. Even though these changes were quite substantial, none of the assessments in 2012 would have been affected by this (as far as could be inferred from the documentation).

The motivation of this change was that few experts had access to sufficiently reliable figures to estimate the population lifetime numerically or by means of population viability analyses. The only alternative available was an expert judgement. Given the long time spans involved, expert judgement of extinction risk of population lifetime can be rather unreliable. Due to the change, the other Red List criteria can now be used as auxiliary criteria: assuming that Red List criteria are comparable, the result can be expressed in terms of lifetime. This will increase the testability of the assessments.

In 2012, population lifetime could be provided in *generations or years*. The former option has been eliminated (in accordance with Sandvik et al. 2013), so that lifetime is *exclusively measured in years*.

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* These measures are readily converted into each other: $\tilde{L}=\bar{L}\cdot\ln(2)$, $P_x=1-e^{-x/\bar{L}}$, $\bar{L}=-x/\ln(1-P_x)$.

Criterion B: expansion speed

In 2012, three different sub-criteria (B_1–B_3) were used to quantify expansion rate. This was not an ideal solution, but simply a result of time pressure, since no common criterion definition could be found that was acceptable to all experts. While all experts could accept at least one of the sub-criteria, this situation had an undesirable consequence: there was no guarantee that expansion rates expressed by different sub-criteria were actually comparable. The novel definition used in 2017 is hoped to overcome both obstacles.

While criterion B was partly referred to as measuring 'spread' in 2012, the new criterion exclusively refers to *expansion speed*. This is in order to emphasise that *expansion* is not equal to *spread* (in the narrow sense of dispersal), as expansion encompasses anthropogenic transport and separate introductions (both intentional and unintentional) in addition to natural dispersal (active and passive).

Definition of expansion

The definition of expansion underlying the set of criteria 2017, is as follows:

***Expansion* is defined as the increase in the number of occurrences.**

Occurrence is here understood as a 2 km × 2 km grid cell colonised by the species (cf. section 2.7.3.), so that expansion is equivalent to an *increase in the area of occupancy* (AOO). The definition has the immediate advantages that it is straightforward to implement, and that it follows the grid-based definition of AOO that is well known from the Red List.

A potential disadvantage of the definition is that the expansion of specialists (which only occur in few grid cells) may be underestimated compared to generalists (which can potentially occur in many grid cells). However, such cases will most likely be taken care of by criterion C (because the reason that specialists occur in few grid cells is the relative rarity of their habitat – in which case criterion C will come into force).

Table II-1: Criteria, scores and threshold values for the classification of the invasion potential of alien species. Changes compared to the 2012 criteria are emphasised using orange font colour.

Criterion	A	B	C
Score for invasion potential	**Median** population lifetime	**Expansion speed**	Colonisation of nature types
1 (small invasion potential)	< 10 years	< **50 m**/a	< 5%
2 (restricted invasion potential)	≥ 10 years **[*AND* B ≥ 2]***	≥ **50 m**/a	≥ 5%
3 (moderate invasion potential)	≥ **60** years [*AND* **B** ≥ **2**]*	≥ **160 m**/a [*AND* **A** ≥ **2**]*	≥ 10%
4 (high invasion potential)	≥ **650** years [*AND* **B** ≥ **3**]**	≥ **500 m**/a [*AND* **A** ≥ **3**]*	≥ 20%

* If the additional condition is *not* fulfilled, the score is to be *reduced by one*.

** **If the additional condition is *not* fulfilled, the score is defined as the *score of criterion B increased by one*.**

NB! *The additional conditions do* not *apply to species that have distance effects or escaped individuals.*

Measurement unit of expansion speed

In principle, one can imagine different ways, or units in which, to measure expansion speed:

- as an *absolute* increase in area, measured in km^2/year;
- as an increase in area *relative to the area colonised at the time of assessment*, measured in %/year;
- as an increase in area *relative to the area that might potentially get colonised*, measured in %/year;
- as an increase in *radius*, measured in m/year.

Of these, the increase in radius has been selected. This implies that:

The measurement unit of expansion speed is *metres per year*.

An increase in radius can be calculated from the increase in area by envisioning all occurrences as gathered in one coherent circular area.* The increase in radius is then the distance with which the circle extends each year in all directions. However, it is important to emphasise that a coherent or circular AOO is no *prerequisite* for measuring expansion in terms of increase in radius (such an assumption would never be met), but rather a way to *illustrate* the meaning of this measure.

One might argue in favour of the other measurement units, e.g. because they may be conceived as more intuitive or as containing more information (about the area colonised, or about the area that is colonisable). The reason for selecting increase in radius nevertheless, is that this unit describes the expansion *potential* of a species, which is a relatively stable quantity. While the other three measurement units are functions of expansion potential, too, they are affected by additional factors, such as time:

- The absolute increase in area, as well as the increase relative to the final area (the area that might potentially get colonised), is *positively related to the duration of the expansion*.
- The increase in area relative to the current area (the area that is colonised at the time of assessment) is *negatively related to the duration of the expansion*.

This might be illustrated graphically or using a numeric example. Figure II-1 shows that a constant increase in radius implies that the absolute increase in area is itself subject to increase over time. The AOO increases each year by the same radius (shown by the orange ring around the circle). Even if this ring, which symbolises the increase, is equally wide each year, its circumference and thus its area increases continuously. Figure II-2 shows how the radius, the increase in radius, the area, and

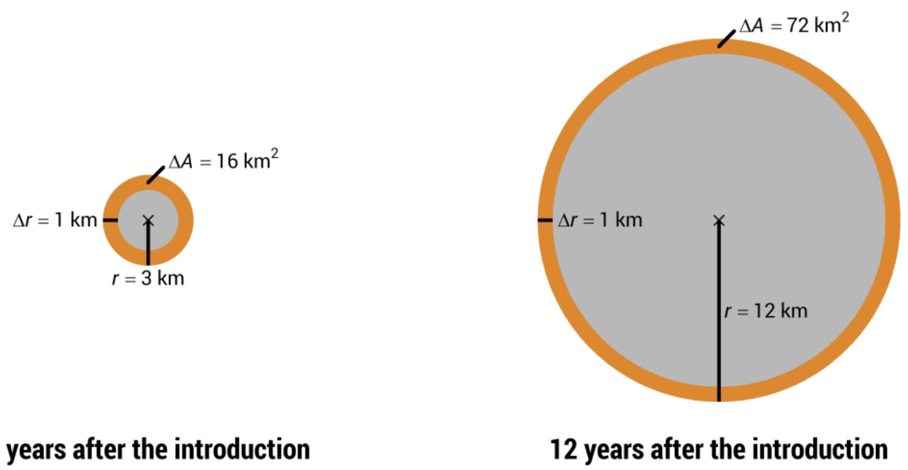

Figure II-1: Illustration of the same expansion process at two different time steps. The grey area is already colonised, the orange area is newly colonised in a given year. Assuming a constant expansion (i.e., assuming a constant radius change Δr per year), the change in area (ΔA per year) will itself increase over time.

* Conversion can be accomplished using the equation $v = (\sqrt{A+\omega\tau} - \sqrt{A})/(\sqrt{\pi}\,\tau)$, where v is expansion speed; A is the area colonised in year t; ω is the increase in area from year t to year t+1; π is pi; and τ is 1 year.

the absolute and the relative increases in area change over time while a species expands until it has colonised its maximum colonisable area of 200 km^2. The only quantity that is constant during this expansion process is the increase in radius.

In order to explain the situation with a numerical example, one should distinguish between three parameters: expansion speed as such, the area that might potentially get colonised, and the current duration of expansion. One can then envisage two different species that are identical with regard to two of these parameters, while they differ in the third. (A further assumption is that expansion speed remains constant until the maximum colonisable area if 'filled up'.) This results in three scenarios:

A	Two species have a current AOO of 1 hectare and will expand up to an AOO of 50 km^2, species 1 expands by 100 m/year, species 2 expands by 1,000 m/year. (This will take 39 years.) (This will take 4 years.)
B	Two species have a current AOO of 1 hectare and expand by 100 metres per year, species 1 up to an AOO of 50 km^2, species 2 up to an AOO of 200 km^2. (This will take 39 years.) (This will take 79 years.)
C	Two species expand by 100 metres per year up to an AOO of 50 km^2, species 1 has a current AOO of 1 hectare, species 2 has a current AOO of 10 km^2. (= it has been expanding for ½ year) (= it has been expanding for 18 years) (This will take 39 years.) (This will take 22 years.)

In scenario A, it is obvious that species 2 represents a greater potential threat for Norwegian nature, because it expands faster than species 1. This is a rather trivial situation, and all four measurement units give the same answer to it. However, one can show with species 1 that it starts its expansion

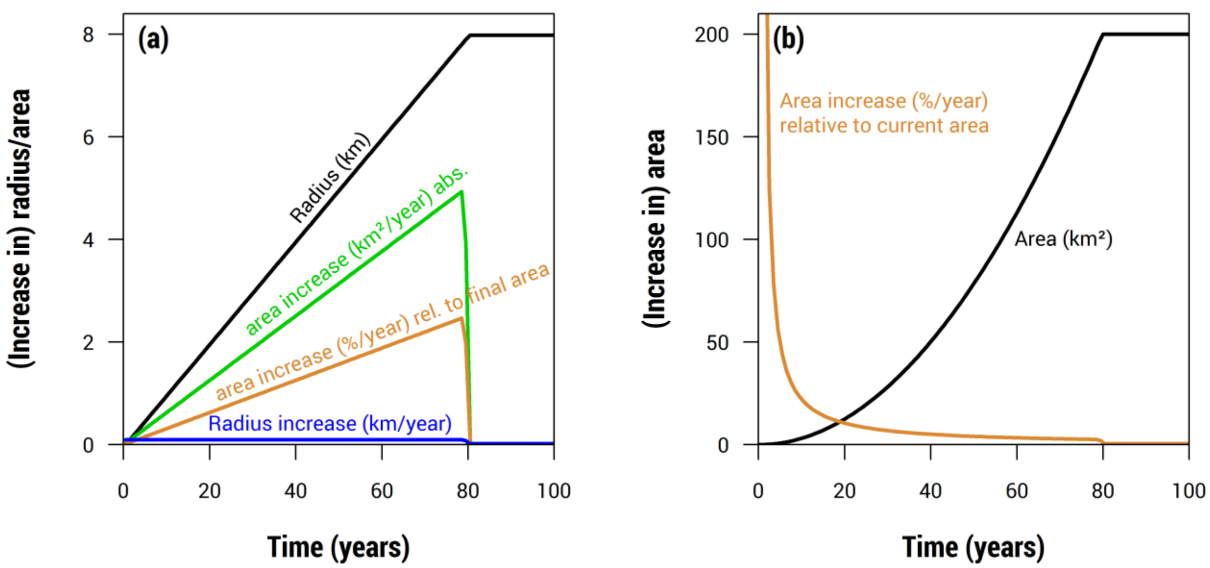

Figure II-2: Example of how different measures of expansion and expansion speed change over time. The figure is based on the assumption of a constant expansion potential, and the maximum colonisable area is set to 200 km^2. Radius change (blue) is constant. The radius (black, panel **a**), the absolute area change (green) and the area change relative to the final area (orange, panel **a**) increase linearly with time. The area (black, panel **b**) increases quadratically with time. Area change relative to the current area (orange, panel **b**) decreases hyperbolically with time.

with a speed of 0.07 km^2/year (from this to the next year). By the last year of the expansion, this speed has increased to 2.45 km^2/year, without the species's characteristics having changed at all. This illustrates that absolute increase in area has to be used with great care, if at all.

In scenario B, both species are equivalent when judged by their increase in radius (100 m/year), their absolute increase in area (0.07 km^2 during the first year), and their increase in area relative to the current area (670% during the first year). One might argue that species 2 should be regarded as a greater threat, because it can colonise a larger area. At first sight, this might be addressed by using increase in area relative to the final area. Upon closer inspection, this does not work out, however: during the first year, the 'nice' species 1 increases by 0.13% of its final area, while the 'bad' species 2 increases by 0.03% of its final area. During the last year of the expansion, the 'nice' species 1 increases by 5.0% of its final area, while the 'bad' species 2 increases by 2.5% of its final area. In other words: the rate of increase, when measured relative to the final area, is *lower* in the species that represents a *greater* threat – opposite to what one might have wished by taking the final area into account.

In scenario C, both species are equivalent when judged by their increase in radius (100 m/year). When judged by their absolute increase in area, species 2 increases more rapidly (1.15 km^2 in the first year, compared to only 0.07 km^2 in the first year for species 1). When judged by their increase in area relative to current area, on the other hand, species 1 increases more rapidly (670% in the first year, compared to only 12% in the first year for species 2). This illustrates that the choice of measurement unit is far from trivial and may give opposite answers. The reason can be seen from Figure II-2, because the absolute increase in area increases with the area colonised, while the increase in area relative to the current area decreases with the area colonised.

One might argue that a greater current area represents a greater threat to Norwegian nature, so that species 2 in scenario C ought to receive a higher risk score. This implies that the risk score for any species increases with time, as long as the species continues to expand. The opposite argument might be put forward, too: species that have been expanding for many years ought to be 'given up', because it is unrealistic to eradicate them. In this case, species 1 in scenario C ought to receive a higher risk score. This implies that the risk score for any species decreases with time, as long as it continues to expand.

However, such arguments are concerned with *management* issues. As such, they are outside the scope of a risk assessment. On this background, measurement units of expansion that take current or future AOO into account, are regarded as unsuitable. The only measure that is unaffected by all this, describing expansion *potential* as such, without mixing in management issues, is the increase in radius (measured in metres per year).

Having said this, it is important to emphasise that knowledge of current and future areas constitute relevant information that ought to be made accessible to biodiversity management authorities. This is better accomplished in the form of supplementary species information in the AlienSpeciesDatabase than by trying to incorporate it into the expansion speed.

From which part of the expansion process should the speed be estimated

The numerical examples and the graphs were based on the assumption of an even increase in radius until the colonisable area is colonised, whereupon it drops to zero. This is an oversimplification: when the species approaches full colonisation of its potential AOO, the speed is likely to decline long before the entire area is 'filled up'. In addition, there are often lag phases, i.e. a delayed start of the expansion.

One such situation is shown in Figure II-3a. The species has the potential to expand up to a radius of 200 km, but the speed varies in the course of the expansion process: it is low to begin with, increases gradually, but starts to decline again when approximately half of the expansion potential is realised. (We assume that the expansion process is completely known, even including its future parts.)

What this means, is that the expansion speed depends on when during the expansion process it is estimated. A standardisation can be achieved in a number of different ways:

- The expansion speed may be estimated for specific points in time, e.g.,
  - the time of assessment ('now' in Fig. II-3b–d) or
  - in the foreseeable future ('50 years from now' in Fig. II-3b–d).
- The expansion speed may be estimated based on the general form of the expansion process (independent of where on this curve the species is situated when assessed), expressed by, e.g.,
  - the average speed (e.g., from 10% to 90% of the final area; Fig. II-3f) or
  - the maximum speed (Fig. II-3e).

Of these, the last option has been selected. This implies that:

> **Risk assessment are to be based on the *highest realistic* value of expansion speed that is measured, estimated or reported.**

This choice can be justified by invoking the precautionary principle. On the other hand, the choice can be rationalised as following directly from the aim of expressing expansion potential as a *propensity*, and independently from contingent facts such as when the species had been introduced. If the current expansion speed was to be used, a species would be assessed as having a low expansion speed while it is in its lag phase or when its expansion process is completed, compared to a species in the middle

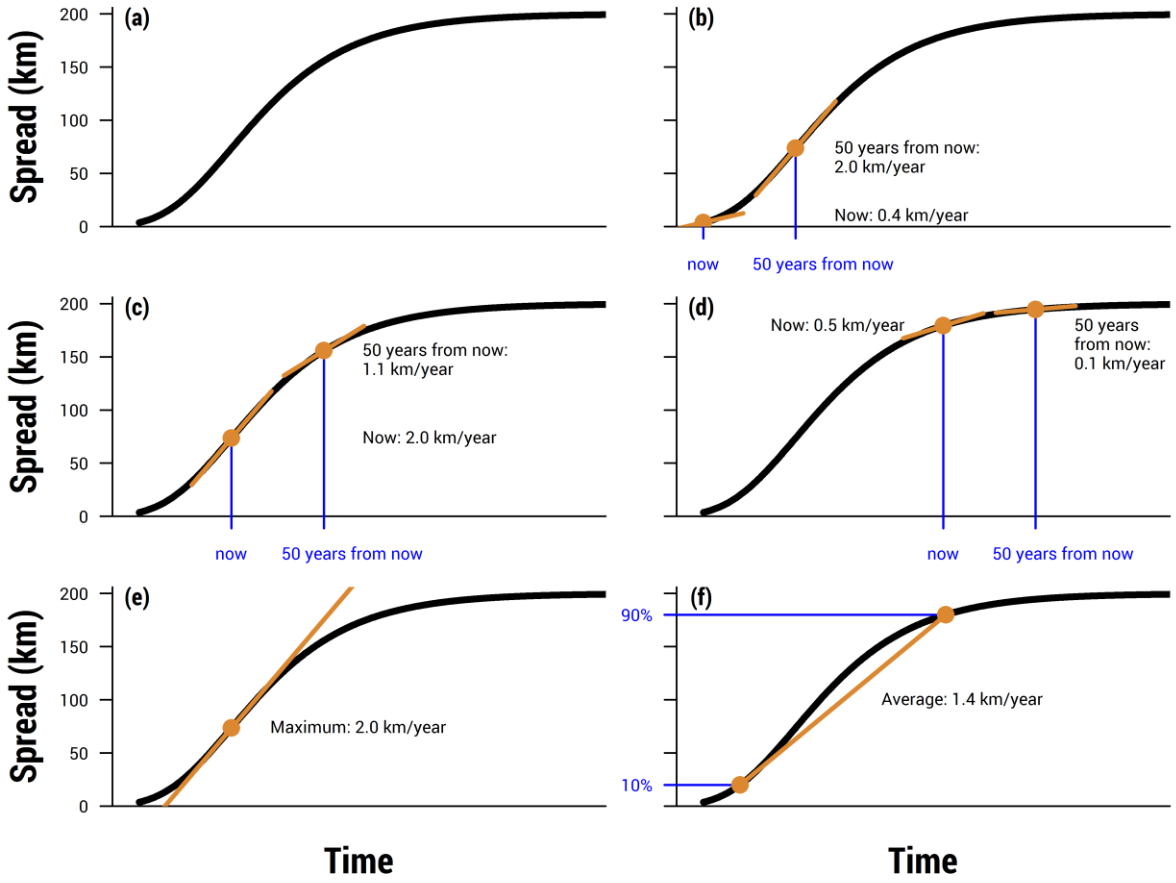

Figure II-3: An idealised expansion process of a species. (a) The curve is sigmoid, and the colonisable area is assumed to be 200 km^2. The slope in a given point of the curve expresses the expansion speed at that point in time. **(b–d)** Estimates of expansion speed will vary, depending on how far the expansion has progressed at the time of assessment, and on whether the speed is estimated for this or a future point in time. Alternatively, expansion speed may be estimated independently of the time of assessment by using **(e)** the maximum value (the steepest part of the curve) or **(f)** the average over a certain time interval (e.g., from 10% to 90% of the final area).

of its expansion process – even if all species these have the same expansion *ability*. This is not a desirable situation. A species that has (almost) completed its expansion, has no (or a low) expansion; as soon as the species is removed from Norwegian nature, however, it will again expand much faster. This is why expansion speed ought to capture the *highest* potential expansion ability.

In many cases, the data available will be insufficient to estimate the entire expansion process. Instead, one may have a certain amount of measurements (point estimates) of the expansion speed. In such cases it is important to ensure that the values are *realistic*, before using the highest value measured. The single highest value may be due to observation error, measurement error or very special (and non-representative) conditions. That is why the use of an upper confidence limit (e.g., the 95th percentile) may be better then strictly using the maximum value.

Other changes regarding the invasion axis

Criterion C has not been changed. However, the interplay between criteria A and B has been adjusted. As explained in the set of criteria (Appendix I), criteria A and B both need to reach a certain level for a species to have an invasion potential. That is why placement along the invasion axis is determined by the *interplay* of criteria A and B, rather than the *maximum* score obtained by A or B in isolation.

Table II-2a shows how the scores for criteria A and B are, in conjunction, translated into a score on the invasion axis (unless criterion C has a higher score). For comparison, Table II-2b shows how the situation was handled in 2012; and Table II-2c shows what it would have meant to let the highest score decide (one-out–all-out principle).

The change from 2012 to 2017 thus only concerns two cells in the table, and entails a down-weighting of criterion A relative to criterion B. The rationale is that the role of establishment (A) and expansion (B) is not symmetrical: a species cannot do much harm to native nature if it spreads very slowly (or not at all), even if it does not go extinct by

Table II-2a. The score for invasion potential (bold figures), as it *is* determined by the scores for criteria A and B (italic figures) according to the *set of criteria 2017*. Changes are shown using orange font colour.

Score for criterion A	Score for criterion B *1*	*2*	*3*	*4*
1	**1**	**2**	**2**	**3**
2	**1**	**2**	**3**	**3**
3	**2**	**3**	**3**	**4**
4	**2**	**3**	**4**	**4**

Table II-2b. The score for invasion potential (bold figures), as it *has been* determined by the scores for criteria A and B (italic figures) according to the *set of criteria 2012*.

Score for criterion A	Score for criterion B *1*	*2*	*3*	*4*
1	**1**	**2**	**2**	**3**
2	**2**	**2**	**3**	**3**
3	**2**	**3**	**3**	**4**
4	**3**	**3**	**4**	**4**

Table II-2c. The score for invasion potential (bold figures), as it *would have been* determined by the scores for criteria A and B (italic figures) according to the *one-out–all-out principle*.

Score for criterion A	Score for criterion B *1*	*2*	*3*	*4*
1	**1**	**2**	**3**	**4**
2	**2**	**2**	**3**	**4**
3	**3**	**3**	**3**	**4**
4	**4**	**4**	**4**	**4**

itself. In contrast, a species that expands rapidly may affect huge areas before it goes extinct. Even if it goes extinct after a comparatively short time (20 years, say, e.g. after an especially severe winter), it may have done great harm by that time.

Table II-2a may expressed algorithmically, too: the combined score of A and B is calculated as $AB = \frac{2}{5}A + \frac{2}{3}B$, where the result is rounded to the nearest integer.

Criteria D, E and H: ecological and genetic effects on native species

As a purely terminological change, interactions that were previously referred to as 'negligible' and 'weak', are now referred to as 'weak' and 'moderate', respectively. More importantly, moderate interactions are now defined as any "interaction that results (or will result) in a reduction of at least 15% in the population size of at least 1 native subpopulation over a 10-year period". Thereby, all terms used to describe ecological effects have now received quantitative definitions.

The term *local effect* has been introduced to designate effects "that affect[...] (and that most likely will remain constrained to) less than 5% of the population size *and* AOO *and* EOO of a native species". While the terms 'unlikely', 'weak' and 'moderate' describe that *strength* of ecological effects, 'local' describes their geographic *extent*. If an effect is local in this sense, the *score is to be reduced by one* when concerning (**D**) weak or moderate effects on threatened or keystone species, (**E**) moderate effects on other native species, (**H**) genetic introgression or (**I**) transmission of existing parasites (see Tables II-3 and II-4). Other criteria (or scores) are not affected by this change.

The rationale of this change is that relatively minor effects could have resulted in high risk scores, even if only a small proportion of the AOO of the native species was affected. This was the case for threatened species in particular, where score 2 was unavailable under criterion D, and where any possibility of genetic introgression resulted in score 4 according to criterion H. In cases where the alien species and the native species affected only overlap to a small extent, such risk scores would have been unreasonably high. Such effects can now be downgraded if it can be documented that they only affect a minor proportion of the population, AOO and EOO of the native species.

Table II-3: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria D–G. Changes compared to the 2012 criteria are emphasised using orange font colour.

Criterion	D	E	F	G
	Documented or likely effect within 50 years on			
	native species		nature types	
Score for ecological effect	threatened or keystone	other	threatened or rare	other
1 (no known effect)	unlikely	weak	unlikely	< 5%
2 (minor effect)	**weak *AND* local**	moderate*	**> 0%**	≥ 5%
3 (medium effect)	weak ***AND* large-scale**	local displacement	**≥ 2%**	≥ 10%
4 (major effect)	moderate* *OR* displacement	large-scale displacement	≥ 5%	≥ 20%

* **If the effect is moderate *and local*, the score is to be *reduced by one*.**

Criterion F: effects on threatened or rare nature types

In accordance with the explanations just provided, a score of 2 is now also obtainable under criterion F. Previously, any effect on threatened or rare nature types had received a score of 3. Under the current definition, state changes must affect at least 2% of the AOO of a nature type within a time frame of 50 years, before they receive a score of 3.

Criterion I: transmission of parasites and pathogens

Criterion I has been modified by constraining the score to the maximum score for ecological effect that is (or would have been) assigned to the parasite transmitted. Without this adjustment, a score of 4 might have been assigned to an alien *host* of an alien parasite, just for transmitting this parasite, even though the effect of the *parasite* itself on its native hosts was classified as a score of merely 2. The modification removes the possibility for such counterintuitive results.

Acknowledgements

Many thanks to the members of the reference group (Anders G. Finstad, Lisbeth Gederaas, Hanne Hegre Grundt, Toril L. Moen, Trond Rafoss, Olav Skarpaas) for their invaluable help during the revision of the set of criteria.

Table II-4: Criteria, scores and threshold values for the classification of the ecological effect of alien species, criteria H and I. Changes compared to the 2012 criteria are emphasised using orange font colour.

Criterion	H	I
Score for ecological effect	Documented or likely transmission of genetic material	Documented or likely transmission of parasites or pathogens**
1 (no known effect)	unlikely	unlikely
2 (minor effect)	**locally to native species**	existing parasites to existing hosts such that prevalence increases*
3 (medium effect)	**large-scale** to native species	existing parasites to novel hosts*
4 (major effect)	to threatened or keystone species*	existing parasites to novel threatened or keystone hosts* *OR* of alien parasites

* **If the effect is merely *local*, the score is to be *reduced by one*.**

** **The score of the host must not exceed the score that the parasite obtains for ecological effect.**

III. Quantitative versus qualitative sets of criteria

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The set of criteria used here applies exclusively quantitative rather than qualitative criteria. *Quantitative* criteria are criteria employing precisely defined, numerical thresholds, like the ones used by the Red List (IUCN 2012, Henriksen and Hilmo 2015). When criteria are described using a scale of purely subjective terms (such as 'low', 'limited', 'moderate', 'medium', 'high', 'severe'), on the other hand, they are referred to as *qualitative*. Finally, *semi-quantitative criteria* constitute a middle ground, where criteria are defined not by numbers, but using as concise verbal descriptions as possible.

The criteria A, B, C, F and G of this set of criteria are obviously quantitative. Criteria H and I, while having verbal descriptions, are based on yes/no questions that can be expressed numerically. The threshold 3/4 of criterion I can for instance be described as a choice between statement [3], "the species transmits 0 existing parasites to ≥ 1 threatened species and 0 alien parasites to ≥ 1 native species," and statement [4], "the species transmits ≥ 1 existing parasites to ≥ 1 threatened species or ≥ 1 alien parasites to ≥ 1 native species."

In the 2012 risk assessment, criteria D and E were still semi-quantitative (Gederaas et al. 2012), and therefore the entire set of criteria was referred to as semi-quantitative (Sandvik et al. 2013). Now, the terms 'local' versus 'large-scale' (< 5% versus ≥ 5% area affected), 'weak' versus 'moderate' (< 15% versus ≥ 15% reduction in population size) and 'displacement' (≥ 1% reduction in area) are defined quantitatively. Thereby, the entire set of criteria has become quantitative.

Advantages of quantitative criteria

Quantitative risk assessments have a couple of advantages over qualitative risk assessments (see Sæther et al. 2010:46–51 and references therein). The most important among these are increased repeatability, testability, transparency, adjustability and comparability:

1) *Repeatability*. – A risk assessment is repeatable if different experts would have ended up with the same result (i.e., scores), given that the same information was available to them. Qualitative assessments have low repeatability, because different experts can have different understandings of terms such as 'moderate' and 'high'. No method will ever reach a repeatability of strictly 100%, since subjectivity can enter in a number of ways (see below). However, *by using a quantitative set of criteria, the interpretation of the criteria is standardised*, and repeatability is increased considerably. For example, different experts will agree that a species should obtain a score of 3 according to criterion A, given that the best estimate of the median population lifetime is 100 years (because 60 years < 100 years < 650 years). In contrast, different experts will not necessarily agree whether a median population lifetime of 100 years qualifies as 'limited' or 'moderate'.
2) *Testability*. – A risk assessment is testable if there are objective criteria for deciding whether doubt, disagreement or novel findings require a revision of the assessment. Quantitative risk assessments are testable in this sense. If, for example, the lifetime of a species has obtained a score of 3 according to criterion A, it is obvious what kind of information would be required in order to change this conclusion: if novel findings indicate that the lifetime is actually lower than 60 years or higher than 650 years, a revision is necessary. In contrast, qualitative assessments are not testable: if the lifetime of a species is assessed to be 'moderate', it is far from obvious what kind of information would be needed to change this conclusion.

3) *Transparency*. – The result of a quantitative risk assessment is transparent for all scientists, users, organisations or private persons interested. In other words, it is obvious how the scores were derived from the underlying data, and how the final impact category is derived from the scores. Likewise, it is easy to test whether and how specific assumptions (e.g., regarding observability; Clark et al. 2003, Hooten and Wikle 2008) affect the assessment.
4) *Adjustability*. – Existing risk assessments can get outdated for a number of reasons, including the accumulation of new knowledge about the species's ecology and demography, or changing environmental conditions (Mainka and Howard 2010, Huang et al. 2011). A qualitative risk assessment cannot incorporate such novel information without carrying out a new complete assessment. In contrast, a quantitative risk assessment can be updated one criterion at a time, because the final impact category is uniquely determined by the scores.
5) *Comparability*. – The interpretation of qualitative criteria is always affected by the reference framework of the experts carrying out the assessments (cf. Tversky and Kahnemann 1974). What an expert means by saying that dispersal speed is 'moderate', will for instance depend on whether the term is used by an expert on birds or by an expert on snails. Therefore, qualitative risk assessments will not normally be able to assure that criteria are interpreted in a way that is comparable across different groups of organisms. By reducing the scope of potential interpretations, quantitative criteria achieve a higher comparability.

As a disadvantage of quantitative sets of criteria, it might be mentioned that they demand more of an expert and the data. Risk assessments are thus often easier and less time-demanding when qualitative criteria are used.

Combining quantitative criteria with expert judgement

The choice of a set of criteria does not change the kind of data that is available. A quantitative set of criteria is at its best when numeric estimates are available for the parameters that make up the criteria. If good data are absent, on the other hand, it is more challenging to score a species. In such cases, experts are asked to carry out 'expert judgements' based on their discretion and their personal scientific expertise. This means that even a quantitative set of criteria is not able to avoid subjectivity entirely. It is therefore important to point out that *expert judgements are not incompatible with a quantitative method, as long as they are documented and based on the threshold values*. The documentation will in such cases consist in substantiating that the true parameter value is likely to lie between two specified threshold values. It does not need to produce a single numerical estimate.

Exemplifying this with criterion A, an expert judgement is based on the threshold values when the expert assesses a species to have a median population lifetime between 10 and 60 years, even if no specific lifetime (e.g., 49.2 years) is provided. Even if this judgement is subjective and may turn out to be erroneous, it has a clear advantage over qualitative judgements: *the result is testable*. In other words, it is obvious what kind of evidence is needed in order to change the judgement, viz. documentation that median lifetime is below 10 years or above 60 years. The search for more knowledge can thus concentrate on the question: are there any empirical findings suggesting that the species may have a median lifetime of more than 60 years? Had the median lifetime been describes as 'moderate', it had been far from obvious what kind of evidence was needed in order to overthrow the assessment.

This example illustrates two important points:

The advantage of a quantitative over a qualitative set of criteria is not necessarily that the risk assessment becomes *more correct*, but that it becomes *more correctible*.

The advantage of a quantitative over a qualitative set of criteria is not necessarily that the risk assessment attains a *better certainty*, but that it attains a *better quantifiable uncertainty*.

Handling uncertainty in quantitative sets of criteria

Quantitative sets of criteria have at times been criticised for hiding away the uncertainty in the risk assessment, or for making the results appear "more unimpeachable than they really are." The previous section should have shown that this is based on a misunderstanding. Still, it is important to explain how uncertainty is handled.

To start with, all risk assessments (as all science in general) is imbued with uncertainty. Therefore, the relevant question is not whether a scientific finding is 'certain' (the answer to that is always 'no'); it is whether uncertainty is so large as to affect the interpretation of the result. In the case of a risk assessment, this means that the question is: is uncertainty still within one of the impact categories, or does it cross one or more threshold values? In Figure III-1a, uncertainty is illustrated using the length of an ellipse. It shows that species A and B can unambiguously be placed in a certain category, even though the uncertainty about B's characteristics is much larger. On the other hand, the uncertainty about C's characteristics diffuses upwards, in a way that affects the choice of impact category.

Generally speaking, there are three factors contributing to uncertainty: (1) natural variation, (2) measurement error plus observation error, and (3) semantic uncertainty. Scientists can influence some, but not other sources of uncertainty: the choice of an appropriate method can reduce, but not eliminate measurement and observation error. Natural variability is entirely unaffected by methodology. In contrast, methodology has a huge effect on semantic uncertainty, i.e., on the *scope of potential interpretations* that can be given to the questions posed, to the definitions used and to the criteria applied.

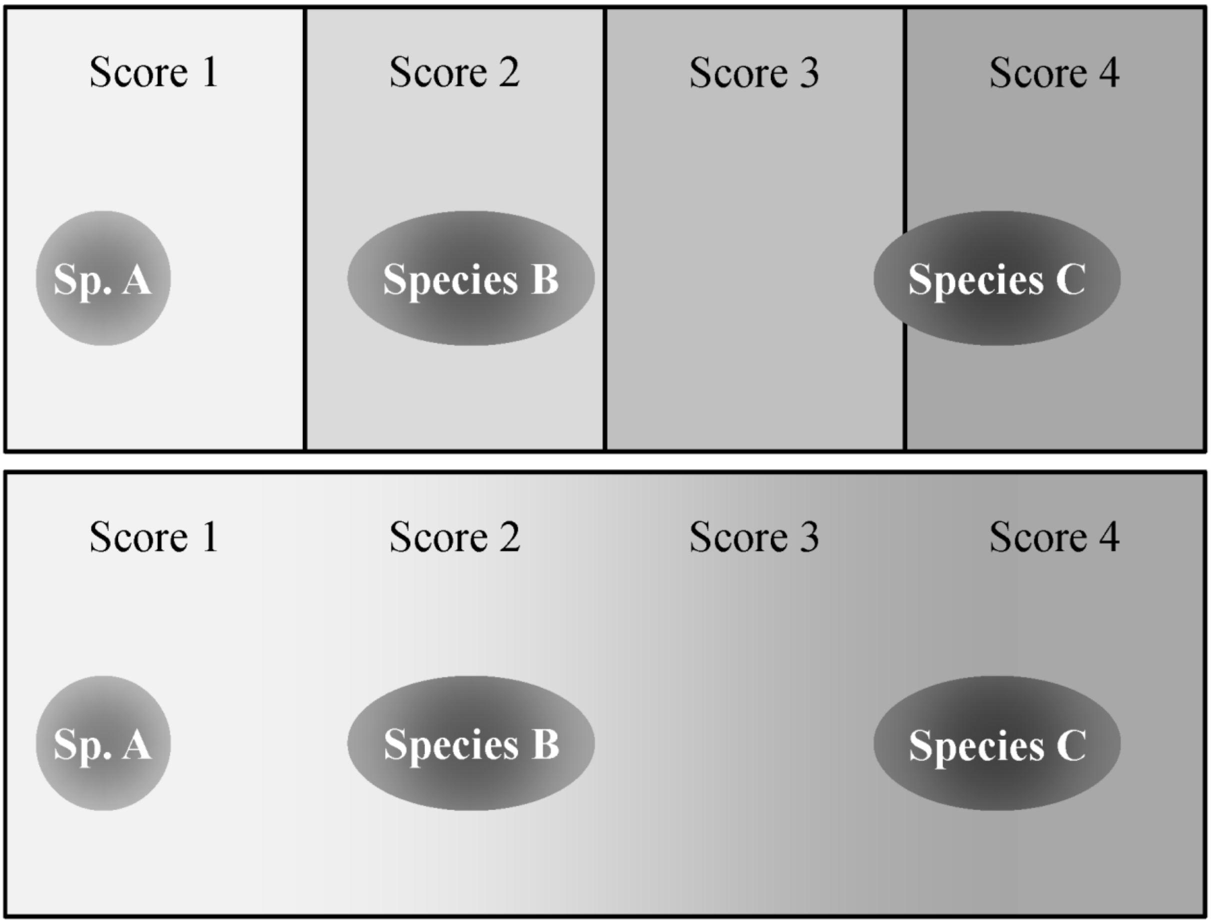

Figure III-1: Concept figure illustrating three species in an (a) quantitative and a (b) qualitative set of criteria.

The difference between qualitative and quantitative sets of criteria affects the last point only: the use of precisely defined (ideally numerical) threshold values is as step towards reducing semantic uncertainty. In a quantitative set of criteria using sharply defined threshold values (Fig. III-1a), some species will fit into a certain category (A and B), while others may fall between two categories (C). If one chooses a qualitative set of criteria instead (Fig. III-1b), species A will still fit into one category and C will fall between two; in addition, however, it has become unclear whether species B belongs to category 2 or 3. As can be seen from Figure III-1a, this uncertainty is not due to poor data; it is due to the categories allowing different interpretations. This can even have the opposite effect, since some may argue that C fits perfectly into category 4. (In the latter case, semantic uncertainty results in an underestimate of the remaining uncertainty.)

The following table shows the nature of the results obtained, given a certain set of criteria and a certain type of data:

	The set of criteria is ...	
Type of data available	**quantitative**	**qualitative**
numerical estimates	repeatable testable	*not repeatable* *not testable*
expert judgements	*not repeatable* testable	*not repeatable* *not testable*

As can be seen, a quantitative set of criteria does *not* guarantee that the results are *repeatable* (for this to be the case, the data need to be numerical in addition). However, it does guarantee that the results are *testable*. A qualitative set of criteria can neither guarantee repeatability nor testability (not even when numerical data are available).

Preferring a qualitative set of criteria because numerical estimates are not (always) available, essentially entails subscribing to the statement: "When results are not repeatable, they ought not to be testable either." As Figure III-1 shows, this is equivalent to the statement: "When the observation error is large, we ought to increase the semantic uncertainty, too." However, there is no conceivable reason to follow such an argument. All means of reducing uncertainty are welcome.

At the same time, it is obvious that uncertainty is not reduced by ignoring, hiding or under-communicating it. Therefore, it is important that the uncertainty inherent in risk assessments is *visualised* in the results and *communicated* to users. Although it may be challenging to communicate uncertainty to lay people, this challenge is unaffected by whether the set of criteria used is qualitative or quantitative.

As a final point, it may be that erroneous conceptions of, or unrealistic expectations to, natural science are one source of misunderstandings by the public. If you conceive of science as a procedure that produces certainties, you are in obvious danger of misunderstanding risk assessments of alien species (as well as all other results of scientific activity). This source of misunderstanding [may be remedied by some reading of Karl Popper (e.g., 1934, 1984, 1994), but it] lies outside the scope of this risk assessment.

IV. Pathways of introduction

The table on page 71 presents the internationally standardised categorisation of pathways of introduction (Hulme et al. 2008, CBD 2014). These categories are used when describing pathways (see section 3.4.). A more detailed description can be provided in the appropriate text box.

Cause	Category	Subcategory
Import *[purposeful import of the species]*	(1) **Release** in nature *[intentional]*	• for use [commercial] • for biological control • for hunting • for fishery in the wild • for landscape/flora/fauna 'improvement' in the wild • for erosion control / dune stabilisation • for conservation purposes or wildlife management • other intentional release
	(2) **Escape** from confinement	• from agriculture • from forestry (including afforestation or reforestation) • from horticulture • from ornamental purpose other than horticulture • of farmed animals • from fur farms • from aquaculture/mariculture • of live food or live bait • of pet/aquarium/terrarium species [private] • from botanical gardens / zoos / aquaria [public] • from research and ex-situ breeding (in facilities) • other escape from confinement
Transport	(3) **Contaminant**	• as parasites on animals (hosts/vectors) • as contaminants on animals (except parasites) • as parasites on plants (hosts/vectors) • as contaminants on plants (except parasites) • of seed • of food (including live food) • of bait • of timber • of habitat material (soil, vegetation, ...) • of nursery material
	(4) **Stowaway**	• with people and their luggage/equipment • in or on vehicles (car, train, ...) • in or on airplanes • in or on ships/boats • with ballast water [or ballast sand] • as hull fouling • with machinery/equipment • with containers/bulk • with organic packing material, in particular wood • with angling/fishing equipment • with other means of transport
Spread	(5) **Corridor**	• interconnected waterways/basins/seas • tunnels and land bridges
	(6) **Unaided**	• natural dispersal across borders of alien species that have been introduced through pathways 1 to 5

V. Nature in Norway

Nature types are relevant both for the description of the ecology of alien species (see chapter 4.) and for the risk assessment (via the criteria C, F and G). All references to nature types are based on NiN (*Nature in Norway*; Halvorsen et al. 2015; see NiN's online version). This Appendix provides an overview of NiN, defines the terms *threatened*, *rare* and *heavily modified* nature, and explains how state changes in nature types can be quantified.

Overview of Nature in Norway

Nature in Norway (NiN) is a system for classifying and describing all variation in nature. The *typification system* allows a subdivision of nature in Norway into well-defined nature types. The *descriptive system* consists of variables encompassing the variation that exists both within and between nature types.

A typification of nature can be accomplished at different scales or levels. NiN's primary diversity level – and the only one to be used in relation to alien species – is the level of ecological systems (NiN's remaining levels are the landscape/seascape, ecological complex, ecological component, and microhabitat). An *ecological system* is defined as "all organisms within a more or less uniform and delimitable area, the total environment they live in and are adapted to, and the processes that regulate the relationships between the organisms and the environment (including human activity)."

The typification on the ecological-system level is completely contiguous, and it covers the natural variation at the ecosystem level on a relatively fine spatial scale, which allows mapping at scales between 1 : 500 and 1 : 20 000. Nature types are organised into a hierarchy consisting of three levels: major-type group, major type and basic type. For terrestrial systems (T and V), NiN offers 'mapping units 1 : 5 000' as an additional level between the major and basic type. The seven major-type groups on the ecological-system level are:

- *non-wetland terrestrial systems* (T) with 45 major types (e.g., forest, boreal heath, tidal meadow) and 344 basic types;
- *wetland systems* (V) with 13 major types (e.g., ombrotrophic mire, mire and swamp forest, wet snow-bed and snow-bed spring) and 91 basic types;
- *marine seabeds* (M) with 15 major types (e.g., deep stable seabed, shallow sediment bed, coralline seabed) and 195 basic types;
- *freshwater beds* (L) with 8 major types (e.g., deep sediment freshwater-bed, freshwater-spring bed, helophyte freshwater swamp) and 47 basic types;
- *marine water masses* (H) with 4 major types (e.g., ocean water masses, water masses in fjords and rock pools) and 17 basic types;
- *open freshwater* (F) with 5 major types (e.g., river water, circulating lake water) and 34 basic types;
- *snow and ice systems* (I) med 2 major types (snow and ice-covered ground, polar sea ice) without basic types.

The descriptive system handles all the variation there is in nature. NiN distinguishes between local environmental variation and other sources of variation. *Local environmental variation* is defined as "variation in environmental conditions that creates patterns on a relatively fine spatial scale (usually < 1 km) that are stable over relatively long periods of time [usually more than 100(–200) years]". It is described using a set of 57 local (complex) environmental variables. Examples of these are exposure to erosion (ER), content of organic material (IO), natural manuring (NG), lack of oxygen (OM) and water saturation (VM). Local environmental variables are used to define nature types.

The remaining variation is described using nine *sources of variation* that are not captured by the local environmental variables (either because they vary on a different spatial or temporal scale, or because the magnitude of variation is too low to be captured by the typification system). Some of these are relevant for alien species:

- Regional ecological variation (bioclimatic zones, bioclimatic sections etc.) affect the *distribution* of alien species.
- Anthropogenic objects (buildings etc.) define what is meant by 'indoor Norway'.

Three sources of variation contain variables that can undergo change due to alien species:

- species composition (describing the occurrence and quantity of species),
- spatial structure variation (tree-layer stratification, water depth etc.),
- variation in condition and state (eutrophication, acidification etc.).

Both the typification system and the descriptive system are used in connection with the risk assessment of alien species. The typification system is used in order to describe the distribution of alien species. The descriptive system is mainly used in order to quantify the effects that alien species have on nature.

Threatened and rare nature types

The above description is based on NiN 2.0 (*Nature in Norway*, version 2; Halvorsen et al. 2015). Unfortunately, the current Red List of nature types (Lindgaard & Henriksen 2011) is still based on NiN 1.0 (*Nature types in Norway*, version 1; Halvorsen et al. 2009), which used a different typification system than NiN 2.0. The only criterion affected by this is F, which still makes reference to the 'old' typification system. The Red List of nature types contains

- 23 vulnerable nature types,
- 15 endangered nature types, and
- 2 critically endangered nature types (earth pyramid, mowable mire margin).

In addition, 3 nature types are regarded as 'rare' (i.e., near threatened according to Red List criteria 2 or 3), viz. clay slide, lime-poor mire, hydrothermal vent.

Heavily modified nature

The assessment area for the invasion potential and effects of alien species is basically the whole of Norway. However, there are two general exceptions from this rule (see section 2.6.3.):

- Indoor occurrences are to be disregarded in the assessments.
- For production species, their production area is likewise to be disregarded.

For three of the criteria – and only these – there are some additional nature types that are to be disregarded:

> **Criteria C, F and G must not be used to assess occurrences or effects of alien species in or on heavily modified nature.**

NiN defines *heavily modified nature* as "ecosystems characterised by a high intensity of anthropogenic disturbance, often brought about by interferences that have changed the structure and/or other features of the system so strongly that the resulting ecosystem, the food chain, the seed bank and biotic relationships such as mycorrhiza etc. are disrupted or absent." Heavily modified systems are distinguished from semi-natural systems by the latter having a lower intensity of anthropogenic disturbance, so that they are not "thoroughly changed" and do not "cease to be a coherent system".

Anthropogenic disturbance includes, among other factors, *agricultural management*, defined as "regular anthropogenic activity that maintains specific nature types by means of disturbance, potentially in combination with measures for facilitating agricultural productivity, such as mowing, grazing and trampling of livestock, burning, soil management, clearing, flushing of eradicants, manuring, harvest of the tree layer, sowing and watering."

Heavily modified nature is in NiN described using three local environmental variables:

- modified ground without agricultural management, characterised by human disturbance (SX),
- high modification of water bodies (SY),
- agricultural management intensity (HI; basic levels f–j).

Table V-1: Heavily modified nature. Occurrences or effects that alien species might have in or on the nature types in this list, *are to be disregarded when assessing criteria C, F and G*. The same applies to other nature types if they are characterised by intense agricultural management. Please note that 'heavily modified' is abbreviated as 'HM'. (Source: NiN 2.0, Halvorsen et al. 2015, 2016)

Code	Name	Example	Number of basic types
F4	Heavily modified river water	irreversibly contaminated river	3
F5	Heavily modified lake water	water dam	4
H4	Heavily modified marine water masses	fish farm	4
L7	Modified hard freshwater-bed	flooded rock	3
L8	Modified sediment freshwater-bed	contaminated / regulated lake bed	7
M14	Modified stable seabed	oil rig	3
M15	Modified sediment seabed	sea disposal site	4
T35	Modified sediment	gravel tip	4
T36	Dried-out wetlands and freshwater system	HM systems on previous wetland	3
T37	Artificial sediment	asphalted area	3
T38	Tree plantation	monoculturally forested area	1
T39	Modified hard surface	rock laid bare	8
T40	Meadow-like modified system	roadside, airfield	1
T41	Meadow-like cultivated system	HM system similar to semi-natural ones	1
T42	Flower bed and the like	often-treated, intensely managed system	1
T43	Lawn, park and the like	lasting, intensely managed system	1
T44	Arable land	ploughed system	1
T45	Cultivated permanent meadow	manured, sowed, watered system	4
V11	Peat quarry	exposed peat	2
V12	Drained peatland	irreversibly drained peat	3
V13	Artificial wetland system	flooded arable land	3

SX and SY are defining variables for a set of nature types (ecological system major types), which are listed in Table V-1. These nature types are always regarded as heavily modified and are *never* to be included in assessments of criteria C, F and G.

Agricultural management intensity is different from SX and SY in that the former is a continuous variable, and that it is applicable across different nature types. A nature type is regarded as heavily modified if its agricultural management is intense (HI basic levels f–j). If agricultural management is absent (HI-0), consists of grazing only (HI-a) or is of low intensity (HI basic levels b–e), the nature type is regarded as natural or semi-natural (se Halvorsen et al. 2016:135). This means that, in principle, agricultural management intensity needs to be assessed for each occurrence of relevant nature types. Nature types with agricultural management of high intensity are not to be included when assessing criteria C, F and G.

The remaining criteria (A/B, D/E, H/I) are unaffected by all this. In other words, the estimation of, e.g., expansion speed (B), or the assessment of negative effects on threatened species (D) are to be based on occurrences of the alien species in *all* nature types, including heavily modified ones.

State changes in nature types

The criteria F and G are supposed to capture the effect of alien species on nature types. Such effects are quantified in terms of the *proportion of the area of occupancy (AOO) of a nature type that undergoes 'substantial' state changes* due to the presence and activity of the alien species (cf. Table 8 on page 43). If more than one nature type undergoes substantial changes, the score is based on the largest proportion recorded in any nature type. This type of effect demands definitions of the terms 'state change' and of 'substantial'.

> ***State changes* can be defined, by reference to NiN's descriptive system (Halvorsen et al. 2015), as a change in (a) the local environmental variation, (b) the variation in its condition or state, (c) its species composition or (d) its spatial structure variation.**

Table V-2 provides an overview of the environmental variables that might be affected by alien species. Each of these is divided into specifically defined levels. The thresholds between levels are described in the table, too.

> **Generally, a state change is regarded as *substantial* if it encompasses more than a third of the levels that are defined for the relevant environmental variable. However, if the variable has well-defined (countable) levels, a change of one level is sufficient.**

The minimum number *n* of levels required for a state change to be substantial, varying from one to five, is provided in the 'levels' column of Table V-2. If states are undergoing change for other reasons, the effect of the alien species is regarded as substantial only if the change amounts to *n* levels *more* than it had been in the absence of the alien species.

The variables are shortly explained in Table V-2. A detailed description can be found elsewhere (Halvorsen et al. 2016). Some examples of effects on nature types are that the alien species

- eutrophicates a lake (7EU – eutrophication; potentially OM – lack of oxygen),
- leads to erosion (ER – exposure to erosion),
- reduces the number of tree layers (9TS – tree-layer stratification),
- changes the vegetation coverage in the shrub layer (1AG-B – species group composition),
- causes the overgrowing of an open landscape (7RA – regrowth succession; SS – sand development),
- thins a forest (7SN – natural tree-density reduction), or
- overbrowses a kelp forest or terrestrial vegetation (7UB – imbalance between trophic levels).

Table V-2 is not necessarily exhausting. If other effects of an alien species on the landscape level can be documented, this should be described in a text box in tab 4 of the AlienSpeciesDatabase. If an alien species causes a nature type to shift basic type or even major type (i.e., if the alien species transforms one nature type into another), this automatically qualifies as a substantial effect.

NB! *The variable 7FA (alien species) is* not *to be used here.* 7FA describes the presence of alien species in a nature type. It would be circular and flawed to use the same variable for characterising the effect of an alien species on a nature type. Criteria F and G are supposed to measure the effect of alien species, not their presence. For the same reason, the variable 7SB-FY-FB [tree-stand regeneration with alien species] must not be used here.

State changes in the species composition

Alien species may lead to a radical shift in the species composition of an ecosystem. Such a shift goes beyond the effects on single native species (which are captured by criteria D and E), and it is therefore possible to describe it as a state changes in nature type(s). The relevant variables are 1AE, 1AG and 1AR (see Halvorsen et al. 2016:58–60). The levels for these variables are provided in Table V-2, and some more explanations are given here:

- *Single species composition (1AE):* This variable is *only to be used if the alien species itself becomes dominant* (or co-dominant or sub-dominant) in a certain locality. A single level of 25% is defined for this specific purpose. In other words, if an alien species obtains a frequency, coverage or biomass of 25% or more in any nature type (based on the quantity that obtains the largest percentage), this is regarded as a substantial state change in the nature type affected.
- *Species group composition (1AG):* This variable is used to describe changes in the frequency, coverage or biomass *between* functional, structural or taxonomic species groups. Examples of species groups are the tree, shrub, field and bottom layers in terrestrial systems; or the top, intermediate, bottom layers and sessile megafauna in freshwater beds and marine seabeds. Examples of substantial state changes are thus a reduction of the coverage of the tree layer from > 75% to < 25% to the benefit of the shrub layer; or an increase in the biomass proportion of sessile megafauna from < 10% to > 50% at the expense of the top layer (which consists of large algae).
- *Relative partial species group composition (1AR):* This variable is used to describe changes in the frequency, coverage or biomass *within* the abovementioned functional, structural or taxonomic species groups. Examples of substantial state changes are thus a reduction of the proportion of nemoral broad-leaved trees within the tree layer from > 25% to < 12.5% to the benefit of boreal broad-leaved trees (or of herbs in the field layer to the benefit of grasses, or of lichens in the bottom layer to the benefit of mosses); or an increase in the proportion of crinoids within the sessile megafauna from < 25% to > 50% at the expense of sea fans.

Table V-2 (following page): Variables in NiN's descriptive system that can help quantifying the effects of alien species on nature types. An alien species is regarded as having a substantial effect if it changes any of the variables listed here by at least as many levels as indicated in the 'levels' column (if a nature type is already undergoing change for other reasons, the change caused by the alien species must consist of as many levels *more* than it had been in the absence of the species). Page numbers refer to Halvorsen et al. (2016), which also provides a detailed description of all variables. The list is not necessarily exhaustive – experts are encouraged to consider other variables that may be affected by alien species (except 7FA and 7SB-FY-FB, see text).

Variable	Code	Levels	Description / definitions and thresholds of levels
Exposure to erosion (Halvorsen et al. 2016:130)	ER		the mass balance (whether material is added or removed) in relation to flowing water describes the exposure to erosion
		2	without; weak; clear; disruptive
Lack of oxygen (Halvorsen et al. 2016: 160)	OM		oxygen availability in standing water (per. = periodically)
		2	oxic; per. hypoxic; per. anoxic; anoxic
Sand development (Halvorsen et al. 2016:175)	SS		stabilisation of sand dunes as a result of primary succession (from sand-dominated foreshore via 11 levels to normal forest; see Halvorsen et al. 2016:175f for a description of the levels)
		5	0; a; b; c; d; e; f; g; h; i; j; k; +
Water saturation (Halvorsen et al. 2016:196)	VM		median soil moisture (per. = periodically)
		2	well-drained; per. moist; moist; wet
Single species composition (Halvorsen et al. 2016:58)	1AE		proportion of the alien species (measured as frequency/occurrence/coverage) in a nature type; only one specially defined threshold value is used for this purpose
		1	< 25%; > 25%
Species group composition (Halvorsen et al. 2016:59)	1AG		proportion or coverage of a functional/structural/taxonomic species group (e.g., tree layer, shrub layer, bottom layer etc.)
		3	< 2.5%; > 2.5%; > 5%; > 10%; > 25%; > 50%; > 75%; > 90%
Relative partial species group composition (Halvorsen et al. 2016:59)	1AR		proportion or coverage of partial species groups within a larger species groups (e.g., proportion of herbs in the field layer, or of crinoids in the sessile megafauna)
		2	< 12.5%; > 12.5%; > 25%; > 50%; > 75%
Eutrophication (Halvorsen et al. 2016:484)	7EU		proportion variable (cf. Halvorsen et al. 2016:25; r. = relatively)
		3	none; weak; r. weak; intermed.; r. strong; strong; extreme
Regrowth succession (Halvorsen et al. 2016:503)	7RA		ordered factor variable describing the state of succession (regr. = regrowth, succ. = succession)
in boreal heath	7RA-BH	2	intact; early succ.; late succ.; post-succ.
in semi-natural systems incl. wet meadows	7RA-SJ	2	intact; fallow; early regr. succession; late regr. succession; post-succ.
in semi-natural mire	7RA-SM	2	intact; succession; post-succession
on natural ground	7RA-US	2	initial phase; early succ.; late succ.; post-succ.
Natural tree-density reduction (Halvorsen et al. 2016:520)	7SN		proportion of the standing cubic mass of a forest dying due to ungulates (7SN-HJ), insects (7SN-IN) or fungi (7SN-SO)
		3	< 2.5%; > 2.5%; > 5%; > 10%; > 25%; > 50%; > 75%; > 90%
Imbalance between trophic levels (H. et al. 2016:507)	7UB		proportion of 4 m^2 cells with clear evidence of overbrowsing etc.
		3	< 6.25%; > 6.25%; > 12.5%; > 25%; > 50%; > 75%
Tree-layer stratification (Halv. et al. 2016:100)	9TS		number of well-defined tree layers
		1	0; 1; 2; ≥ 3

VI. Biogeographical regions

When registering the original and current distribution of species (cf. section 3.2), the continent and the climate zone are to be described. The climate zones to be used are based on a simplified version of the Köppen–Geiger classification (Peel et al. 2007). With the help of Table VI-1, climate zones plus continents can be translated into biogeographic regions (ecozones, floral kingdoms etc.).

Whenever possible, the subdivisions of subtropical climate should be used. The reason is that certain subtropical regions can have conditions that are very similar to temperate climate (especially in humid and mountainous regions; there are even occurrences of such climate in tropical latitudes). When unknown, one may tick off 'unspecified subtropical climate'.

Table VI-1: Definition of climate zones and relation to ecozones. The Table shows how climate zones can be translated into the Köppen–Geiger classification and (in conjunction with continent) into biogeographical regions. The latter are abbreviated as An (Antarctic), Au (Australasia), Cp (Cape region), NA (Nearctic), NT (Neotropic), PA (Palaearctic) and PT (Palaeotropic).

Climate zone	Köppen–Geiger classification	Eur.	Asia	Afr.	N./C. Am.	S.Am.	Oc.
Polar							
(ant)arctic, alpine	EF, ET	PA	PA	–	NA	An	–
Temperate							
boreal	Dfc, Dfd, Dsc, Dsd, Dwc, Dwd	PA	PA	–	NA	–[4]	–
nemoral	Cfb, Cfc, Dfa, Dfb, Dsa, Dsb, Dwa, Dwb	PA	PA	Cp[4]	NA	NT	Au
arid	BSk, BWk	PA	PA	Cp[1,2]	NA	NT	–[1,2]
Subtropical							
mediterranean	Csa, Csb, (BSk)[1]	PA	PA	PA	NA	NT	Au
humid	Cfa	PA	PA	Cp[4]	NA	NT	Au
arid	BSh, BWh, (BWk)[2], Cwa	–	PT	PT	NA	NT	Au
mountainous	Cwb, Cwc	–	PT	PT	NT	NT	–
Cape region	(BSk), (BWk), (Csa), (Csb)[3]	–	–	Cp	–	–	–
Tropical							
rain forest, savanna, monsoon climate	Af, Am, Aw	–	PT	PT	NT	NT	Au

1 BSk is here regarded as mediterranean if bordering to Csa or Csb.
2 Minor occurrences of BWk (outside Cape region) are here regarded as arid subtropical climate.
3 BSk, BWk, Csa and Csb in Lesotho, Namibia and South Africa are here regarded as Cape region.
4 Potential occurrences (outside Cape region) are here regarded as mountainous subtropical climate.

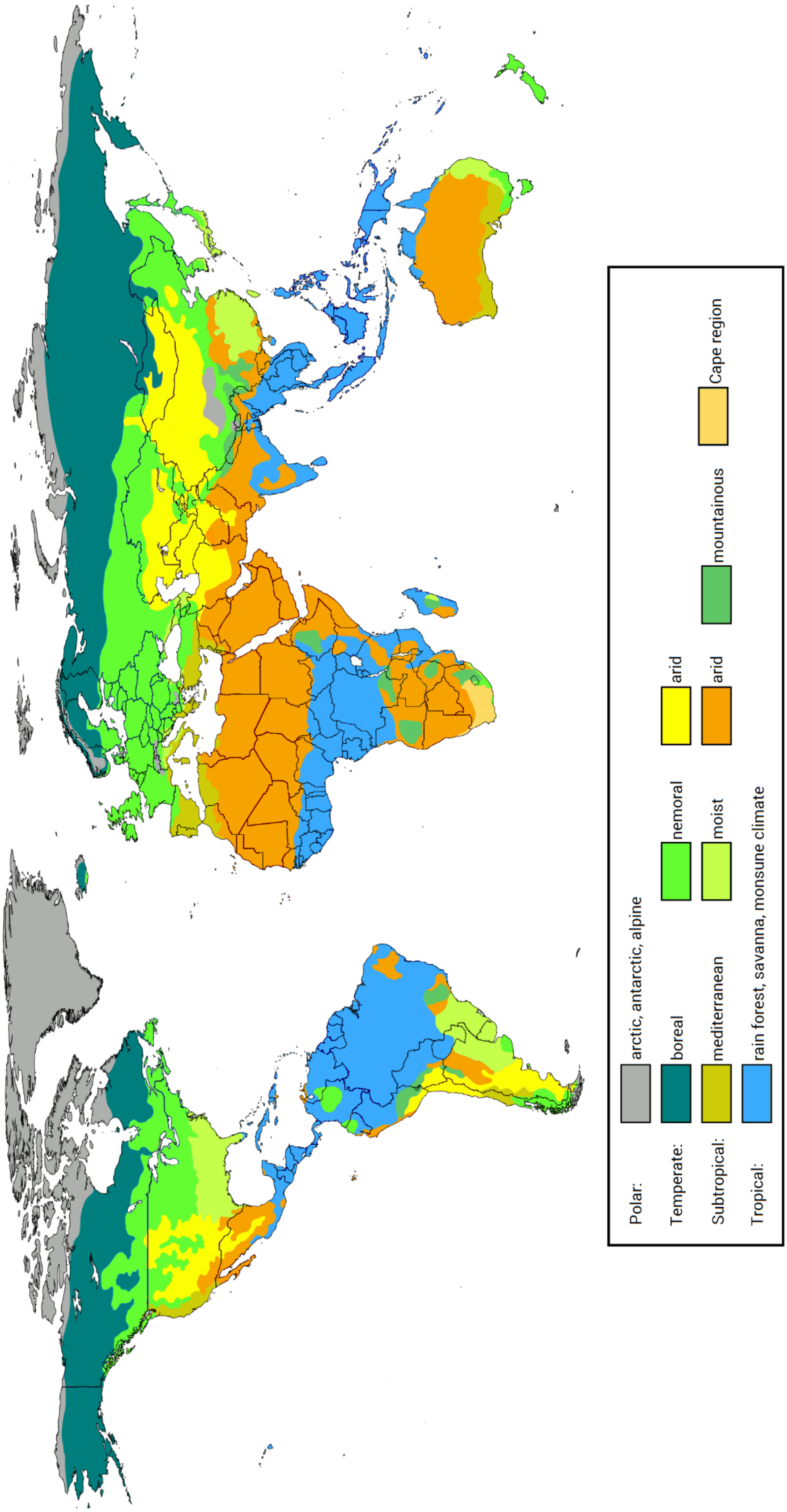

Figure VI-1: Climate zones. (Source: Peel et al. 2007, modified and simplified)

VII. Ecosystem services

When describing a species's non-assessed effects (cf. section 3.2.), mention is to be made of actual or potential effects that the species exerts on ecosystem services. Following TEEB (2010), Lier-Hansen et al. (2013:10) define ecosystem services as "direct and indirect benefits to human well-being obtained from ecosystems. The term encompasses both physical goods and non-physical services that we gain from nature." The following subdivision of ecosystem services is used (Lier-Hansen et al. 2013:134):

- *Supporting services* (basic life processes; ecosystem functions)
  - photosynthesis
  - primary production
  - soil and sediment formation
  - nutrient cycle
  - water cycle
  - evolutionary processes and ecological interactions
- *Provisioning services*
  - food
  - freshwater
  - fibres
  - bioenergy
  - genetic resources
  - biochemical and medical resources
  - ornamental resources
- *Regulating services*
  - air quality regulation
  - climate regulation
  - water flow regulation
  - erosion prevention
  - moderation of extreme events
  - water purification, waste decomposition and detoxification
  - disease control
  - pest control
  - pollination
  - maintenance of soil fertility
- *Cultural services* (experience and knowledge services)
  - recreation, outdoor sports and ecotourism
  - well-being and aesthetic values
  - local identity building
  - spiritual experience
  - religious values
  - inspiration and symbolic perspective
  - knowledge and education
  - natural heritage

VIII. Requested risk assessments of alien species

There are three categories of alien species/taxa that cannot be risk assessed in their entirety (door knockers, regionally alien species, taxa below the species level; cf. sections 2.5., 2.6.2. and 2.6.4., respectively). The Norwegian Environment Agency has requested assessments of the species in Table VIII-1. Experts are asked to consider whether additional species in these three categories should be risk-assessed.

Table VIII-1. Requested risk assessments of alien species. The species are sorted by category (door knocker, regionally alien species, taxon below the species level), thereafter by expert group, thereafter by scientific name. Taxa not listed may still be risk-assessed if experts consider this as relevant.

Scientific name	Norwegian name	Expert group
Door knockers		
Gracilaria vermiculophylla		algae
Barbatula barbatula	smerling	freshwater fish
Carassius gibelio	damkaruss	freshwater fish
Cobitis taenia	sandsmett	freshwater fish
Culaea inconstans	bekkestingsild	freshwater fish
Hypophthalmichthys nobilis	marmorkarpe	freshwater fish
Micropterus dolomieu	småmunnet lakseabbor	freshwater fish
Misgurnus fossilis	dynnsmerling	freshwater fish
Neogobius melanostomus	svartmunnet kutling	freshwater fish
Pelecus cultratus	sabelkarpe	freshwater fish
Rhodeus sericeus	bitterling	freshwater fish
Silurus glanis	malle	freshwater fish
Umbra pygmaea	liten hundefisk	freshwater fish
Vimba vimba	vimme	freshwater fish
Austrominius modestus		marine invertebrates
Carcinus maenas	strandkrabbe	mar. invertebr. (Svalbard)
Chionoecetes opilio	snøkrabbe	mar. invertebr. (Svalbard)
Paralithodes camtschaticus	kongekrabbe	mar. invertebr. (Svalbard)
Scizoporella japonica		marine invertebrates
Nasua narica	hvitneset nesebjørn	mammals
Nasua nasua	søramerikansk nesebjørn	mammals
Sciurus spp.	fremmede ekornarter	mammals
Oncorhynchus gorbuscha	pukkellaks	saltwater fish
Batrachochytrium dendrobatidis	BD	fungi
Batrachochytrium salmandrivorans	BSAL	fungi
Pseudogynoascus destructans		fungi

Scientific name	Norwegian name	Expert group
Regionally alien species		
Abramis brama	brasme	freshwater fish
Carassius carassius	karuss	freshwater fish
Coregonus albula	lagesild	freshwater fish
Coregonus lavaretus	sik	freshwater fish
Cottus gobio	hvitfinnet ferskvannsulke	freshwater fish
Esox lucius	gjedde	freshwater fish
Osmerus eperlanus	krøkle	freshwater fish
Perca fluviatilis	abbor	freshwater fish
Phoxinus phoxinus	ørekyt	freshwater fish
Rutilus rutilus	mort	freshwater fish
Salvelinus alpinus	røye	freshwater fish
Scardinius erythrophthalmus	sørv	freshwater fish
Crangon crangon		marine invertebrates
Eurytemora affinis		marine invertebrates
Mysis relicta	pungreke	marine invertebrates
Podon leuckartii		marine invertebrates
Mus musculus	husmus	mammals
Rattus norvegicus	rotte	mammals
Taxa below the species level		
Acer pseudoplatanus ‘Brilliantissimum’	platanlønn	vascular plants
Acer pseudoplatanus ‘Simon Louis-Freres’	platanlønn	vascular plants
Alchemilla mollis ‘Select’	praktmarikåpe	vascular plants
Amelanchier alnifolia ‘Alvdal’	taggblåhegg	vascular plants
Amelanchier spicata ‘Moelv’	blåhegg	vascular plants
Berberis thunbergii ‘Atropurpurea’	høstberberis	vascular plants
Cerastium tomentosum ‘Silberteppich’	filtarve	vascular plants
Clematis alpina ‘Violet purple E’	alperanke	vascular plants
Clematis sibirica ‘Baikal’	skogranke	vascular plants
Cotoneaster horizontalis ‘Spred’	krypmispel	vascular plants
Cotoneaster lucidus ‘Romsdal’	blankmispel	vascular plants
Laburnum alpinum ‘Pendulum’	alpegullregn	vascular plants
Larix decidua ‘Kornik’	europalerk	vascular plants
Lonicera involucrata ‘Kera’	skjermleddved	vascular plants
Lonicera involucrata ‘Lycksele’	skjermleddved	vascular plants
Lonicera involucrata ‘Marit’	skjermleddved	vascular plants
Lonicera tatarica ‘Arnold red’	tatarleddved	vascular plants
Phedimus hybridus ‘Immergrünchen’	sibirbergknapp	vascular plants
Phedimus spurius ‘Fuldaglut’	gravbergknapp	vascular plants
Phedimus spurius ‘Purpurteppich’	gravbergknapp	vascular plants
Phedimus spurius ‘Scorbuser Blut’	gravbergknapp	vascular plants
Picea sitchensis ‘Silverberg’	sitkagran	vascular plants
Pinus mugo ‘Varella’	buskfuru	vascular plants
Pinus mugo ‘Mughus’	buskfuru	vascular plants
Pinus mugo ‘Ophir’	buskfuru	vascular plants
Pinus mugo ‘Pumilio’	buskfuru	vascular plants
Robinia pseudoacacia ‘Twisty baby’	robinia	vascular plants

Scientific name	Norwegian name	Expert group
Robinia pseudoacacia 'Umbraculifera'	robinia	vascular plants
Rosa rugosa 'Agnes'	rynkerose	vascular plants
Rosa rugosa 'Alba'	rynkerose	vascular plants
Rosa rugosa 'Artropurpurea'	rugosahybrid	vascular plants
Rosa rugosa 'Conrad Ferdinand Meyer'	rugosahybrid	vascular plants
Rosa rugosa 'Dawsons hybrid rugosa'	rugosahybrid	vascular plants
Rosa rugosa 'F.J. Grootendorst'	rugosahybrid	vascular plants
Rosa rugosa 'Flore pleno'	rugosahybrid	vascular plants
Rosa rugosa 'Frau Dagmar Hastrup'	rugosahybrid	vascular plants
Rosa rugosa 'Hansaland'	rugosahybrid	vascular plants
Rosa rugosa 'Johanna'	rugosahybrid	vascular plants
Rosa rugosa 'Magnifica'	rugosahybrid	vascular plants
Rosa rugosa 'Moje Hammarberg'	rugosahybrid	vascular plants
Rosa rugosa 'Ottawa'	rugosahybrid	vascular plants
Rosa rugosa 'Sarah van Fleet'	rugosahybrid	vascular plants
Rosa rugosa 'Schneezwerg'	rugosahybrid	vascular plants
Rosa rugosa 'Signe Relander'	rugosahybrid	vascular plants
Rosa rugosa 'Superba'	rugosahybrid	vascular plants
Solidago sp. 'Strahlenkrone'	gullris	vascular plants
Swida alba 'Aurea'	sibirkornell	vascular plants
Swida alba 'Elegantissima'	sibirkornell	vascular plants
Swida alba 'Ivory Halo'	sibirkornell	vascular plants
Swida alba 'Sibirica'	sibirkornell	vascular plants
Swida alba 'Sibirica variegata'	sibirkornell	vascular plants
Vinca minor 'Elise'	gravmyrt	vascular plants

IX. Red List criteria

One possibility for estimating population lifetime according to criterion A (cf. section 5.1.1.), is the use of Red List criteria. Table IX-1 provides an overview of these criteria and the corresponding threshold values. The criteria are explained by IUCN (2012, 2016) and Artsdatabanken (2014).

The Red List criteria that are most likely to be helpful for assessing alien species (most of which are, after all, relatively recently established), are criteria B (B1 or B2, especially in conjunction with the subcriteria a and c) and D (D1 or D2), with the possible addition of C (especially subcriterion C2b).

Please note that the Red List approach has to be 'turned upside down': what is assessed for alien species is the risk of *not* going extinct. For this reason, time periods are only to be measured in years (*not in generations*, even though some Red List criteria offer this option). If more than one Red List criterion can be assessed, the score reported should be based on the criterion that results in the *lowest* extinction risk. However, knowledge of the species's biology should be taken into account. For example, if an invertebrate of low mobility only occurs at one locality and experiences extreme fluctuations, it is reasonable to score it as CR according to Red List criterion B2(a,c), even if the locality houses 1 500 individuals (which might qualify as NT according to D1).

Table IX-1: Overview of Red-List criteria. (Source: Artsdatabanken 2014:22)

	CR	EN	VU	NT
A. Population reduction				
A1	≥ 90%	≥ 70%	≥ 50%	≥ 25%
A2, A3 and A4	≥ 80%	≥ 50%	≥ 30%	≥ 15%
A1. An observed, estimated, inferred or suspected population reduction during the past 10 years or 3 generations, where the causes of the reduction are clearly reversible, understood and have ceased, based on some of the following alternatives: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in the area of occupancy, extent of occurrence and/or habitat quality (d) actual or potential levels of exploitation and/or utilisation (e) negative impact from introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites				
A2. An observed, estimated, inferred or suspected population reduction during the past 10 years or 3 generations, where the causes of the reduction may not have ceased or may not be understood or may not be reversible, based on (a) to (e) under A1.				
A3. A projected or suspected population reduction during the coming 10 years or 3 generations, based on (b) to (e) under A1.				
A4. An observed, estimated, inferred or suspected population reduction during 10 years or 3 generations, where the time span includes both the past and the future, based on (a) to (e) under A1.				
B. Geographical range in the form of either extent of occurrence (B1) and/or area of occupancy (B2)				
B1. Extent of occurrence	< 100 km^2	< 5 000 km^2	< 20 000 km^2	< 40 000 km^2
B2. Area of occupancy	< 10 km^2	< 500 km^2	< 2 000 km^2	< 4 000 km^2 or ≥ EN + 1 subcrit.
And 2 of the following 3 sub-criteria:				
(a) (i) severe fragmentation or (ii) few localities	= 1	≤ 5	≤ 10	≤ 20
(b) continuing decline in any of (i) extent of occurrence, (ii) area of occupancy, (iii) area or quality of habitat, (iv) number of localities or subpopulations, or (v) number of mature individuals				
(c) extreme fluctuations in (i) extent of occurrence, (ii) area of occupancy, (iii) number of localities or subpopulations, or (v) number of mature individuals				
C. Small population and continuing decline in population				
Number of mature individuals	< 250	< 2 500	< 10 000	< 20 000
And at least one of the following sub-criteria:				
C1. Continuing decline	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 yrs or 3 generations	10% in 10 years or 3 gener., or < 10 000 ind. and 5% in 10 years or 3 generations
C2. Continuing decline and (a) and/or (b)				
(a) (i) number of mature individuals in each subpopulation, or	≤ 50	≤ 250	≤ 1 000	≤ 1 000
(ii) % mature individuals in a subpopulation	≥ 90%	≥ 95%	100%	100%
(b) extreme fluctuations in no. of mature individuals	≥ 10 ×	≥ 10 ×	≥ 10 ×	≥ 10 ×
D. Very small or geographically very restricted population				
D1. Number of mature individuals	< 50	< 250	< 1 000	< 2 000
D2. Restricted area of occupancy or number of localities	Not used	Not used	< 20 km^2 ≤ 5 localities	< 40 km^2 ≤ 10 localities
E. Quantitative analysis				
Indicating that the probability of extinction is at least	50% in 10 years or 3 generations	20% in 20 years or 5 generations	10% in 100 years	5% in 100 years

X. R-script for estimating population lifetime

What follows, are instructions for the **R** function LIFETIME. The program estimates the median lifetime of a population based on demographic parameters of the species. Estimates of population lifetime enter the risk assessment of alien species via criterion A on the invasion axis.

The script was written by Hanno Sandvik (Centre for Biodiversity Dynamics, Norwegian University of Science and Technology). Its current version is 1.6 (as of April 2017).

These instructions are also available online (http://www.evol.no/hanno/12/lifetime.htm). When updated versions are released, they will be available at that URL.

Introduction and installation

The **R** script does not require any previous knowledge of **R**, but presupposed that **R** is installed on the computer. Here is a step-by-step instruction:

- **R** is an open software package that can be downloaded for free at http://www.r-project.org. Please follow the instructions on that site to install the package.
- After you have installed and started **R**, the lifetime script can be loaded in one of two ways:
  - write `load(url("http://www.evol.no/hanno/12/lifetime.rtx"))` directly in your **R** pane (this requires your computer to be online); or
  - use your browser to navigate to http://www.evol.no/hanno/12/lifetime.rtx and save this file to your hard disk; later, write `load("...")` in your **R** pane, where "..." specifies the file location [for example, `load("c:/aliens/lifetime.rtx")`; this requires your computer to be online only when downloading the file for the first time, whereupon it can be loaded locally from your computer].
- Now you can run the script by writing `lifetime(...)`, where "..." represents the parameters, which are explained in detail below. Example:

  ```
  lifetime(N0=200, lambda=1.02, demvar=0.75, envvar=0.1, C=10)
  ```

  Not all parameters are required (see below for details), e.g.:

  ```
  lifetime(N0=50, lambda=0.96, envvar=0.01)
  ```

  Parameter names can be omitted if they are provided in the order `N0`/`lambda`/`demvar`/`envvar`/`C`:

  ```
  lifetime(1000, 1.05, 0.9)
  ```

  is thus identical to

  ```
  lifetime(N0=1000, lambda=1.05, demvar=0.9)
  ```

  Some more parameters can be used if desired (`r`, `K`, `ndis`, `pdis`, `theta`, `varK`, `rho`), although this may not often be needed.

Please note that this **R**-script is not part of any **R** package. Therefore, no **R** help will be available for this function. Please refer to these instructions instead.

Parameters

The function LIFETIME has the following parameters:

`N0` Current population size (N_0). This figure constitutes the basis for estimates of future population sizes.

- Definition: The number of individuals that currently make up the population.
- Significance: The larger N_0, the *larger* is the expected population lifetime (see Fig. X-1a).
- Default: none. The parameter must be specified with a number ≥ 1.

lambda The annual multiplicative population growth rate (λ). If **r** is provided, **lambda** can be omitted.

- Definition: $\lambda = N_{t+1} / N_t$, where *t* is time (year).
- Significance: The larger λ, the *larger* is the expected population lifetime. The parameter has a huge effect on the result (see Fig. X-1b).
- Default: none. Either **lambda** or **r** should be specified. Otherwise, **lambda** is assumed to be 1 (no increase, no reduction), which may be far from correct.

demvar Demographic variance (σ_d^2). This is a measure of the extent of demographic stochasticity.

- Definition: Demographic variance is the variance in fitness *w* (number of surviving offspring per individual) in the population, i.e. $\sigma_d^2 = Var(w) = \frac{1}{N-1}\sum_{i=1}^{N}(w_i - \mu)^2$, where μ is the population's mean fitness.
- Significance: The larger σ_d^2, the *smaller* is the expected population lifetime. At large population sizes, the parameter has minor effects on the result (see Fig. X-1c).
- Default: Exact knowledge of alien species' demographic variance will rarely be available from their novel environments. If the parameter is omitted, it is set to 0.5. This is a realistic assumption for several vertebrates, but can be strongly misleading for other taxa. It should be attempted to specify a realistic value at least for the larger taxon to which the species belongs.

envvar Environmental variance (σ_e^2). This is a measure of the extent of environmental stochasticity.

- Definition: $\sigma_e^2 = \sigma_\lambda^2 - (\sigma_d^2/N)$, where σ_λ^2 is the variance of the multiplicative population growth rate.
- Significance: The larger σ_e^2, the *smaller* is the expected population lifetime. The parameter can have major effects on the result (see Fig. X-1d).
- Default: The estimation of environmental variance requires several years of population estimates for the species in question. This information will often be unavailable for alien species. If the parameter is omitted, it will be set to 0.05. This is a realistic assumption for several vertebrates, but can be strongly misleading for other taxa. It should be attempted to specify a realistic value at least for the larger taxon to which the species belongs. If environmental variance is mainly caused by relatively rare 'disasters' characterised by unusually high mortality, an alternative way of specifying environmental variance is by using the parameters **pdis** and **ndis** (see below).

C Quasi-extinction threshold (*C*). The population size at which the species is regarded extinct. Under most circumstances, it is realistic to assume that this threshold is larger than zero.

- Definition: The largest number of individuals that is sufficiently small to effectively prevent reproduction (e.g., because the inability to find potential mates).
- Significance: The larger *C*, the *smaller* is the expected population lifetime. It is sufficient to provide the correct order of magnitude (see Fig. X-1e).
- Default: If the parameter is omitted, it will be set to 10. Potentially, it can be both lower (down to 1, e.g. in species with vegetative reproduction) and larger (e.g. under strong Allee effects).

r The intrinsic population growth rate (*r*). If **lambda** is specified, **r** will be ignored.

- Definition: $r = \ln\lambda$.
- Significance: The larger *r*, the *larger* is the expected population lifetime. The parameter has a huge effect on the result (cf. Fig. X-1b).
- Default: none. See **lambda**.

K Carrying capacity (*K*).

- Definition: The population size at which density regulation balances the growth rate.
- Significance: The effect of *K* depends on the growth rate. If $\lambda > 1$ ($r > 0$), the larger *K*, the *larger* is the expected population lifetime. If *K* is assumed to be much larger than N_0, the precise value of *K* has negligible effects on the result (see Fig. X-1f). If, however, $\lambda < 1$ ($r < 0$), the larger *K*, the *smaller* is the expected population lifetime.
- Default: Exact knowledge of alien species' carrying capacity will rarely be available from their novel environments. If the parameter is omitted, it is set to 100 times N_0. For most purposes, this is a sufficient approximation. Please note that a negative population trend may be caused by $K < N_0$, rather than by $\lambda < 1$ ($r < 0$). The script can handle both cases. However, please avoid specifying $K < N_0$ and $\lambda < 1$ *at the same time* (this would result in meaningless estimates).

ndis Number of disasters (n_{dis}). If **ndis** *and* **pdis** are provided, **envvar** is ignored.

- Definition: The mean or expected number of 'disaster years' within a 50-year period, where disaster year is defined as a year with unusually high mortality that is caused by an environmental factor common to the entire or large parts of the population.
- Significance: The larger n_{dis}, the *smaller* is the expected population lifetime.
- Default: none. The figure must be ≥ 1 (one disaster per 50 years) and < 50 (one disaster each year). Disasters, defined as episodes during which an unusually large proportion of the population dies through a common environmental effect (such as frosts, fires, droughts), are an alternative way of specifying environmental variance. It is based on the assumption that environmental variance is in its entirety caused by such disasters. Note that the population growth rate (**lambda** or **r**) must be specified for an average *non-disaster year*.

pdis Extent of disasters (p_{dis}). If **pdis** *and* **ndis** are provided, **envvar** is ignored.

- Definition: The proportion of the population dying in a disaster year *over and above* normal mortality.
- Significance: The larger p_{dis}, the *smaller* is the expected population lifetime.
- Default: none. The value must be a fraction larger than 0 (no additional individuals dies during a disaster year than during a normal year) and less than 1 (all individuals die during a disaster year). See **ndis** for further explanations.

Further parameters are available, although they may rarely be needed. The ones that are implemented thus far are:

- **quiet** (suppresses messages and warnings if it is **TRUE**; defaults to **FALSE**),
- **theta** (the value used for θ in theta-logistic population models; the default is **theta=1**, which assumes logistic population dynamics; if **theta=0**, density dependence follows the Gompertz law),
- **varK** (the variance of carrying capacity on a logarithmic scale, $\sigma^2_{\ln K}$; defaults to 0),
- **rho** (the environmental correlation ρ between population growth rate and environmental noise; defaults to 0),
- **language** (possibility for switching to Norwegian output; correspondingly, the following parameters exist: **envvar = milvar**, **ndis = nkat**, **pdis = pkat**, **quiet = hold.munn** and **language = spraak**),
- **kontroll** (a list of control parameters that can have the following entries:
  tol = number specifying the relative error tolerance during integration;
  sub = maximum number of subdivisions during integration;
  kor = number specifying the weighting of estimation error during integration;
  det = logical variable indicating whether detailed error messages should be displayed;
  tra = logical variable indicating whether parameters should be transformed to $N_0 = 10$;
  def and **int** are reserved for internal control routines).

Output

The output of the function is a number, representing the population's median lifetime in years. Some additional information is displayed on the screen only (provided you didn't specify `quiet=TRUE`), viz. conversions of the result into different equivalent quantities (extinction risk, expected lifetime and median lifetime).

Estimation may take several minutes (especially when the population size is high). If you get unexpectedly high or low estimates, this *may* be due to convergence problems during estimation. If you suspect that this is the case, or if the program produces error messages, this may be a bug, and you are welcome to send me the input parameters that produced them (although I cannot guarantee that I will be able to help you).

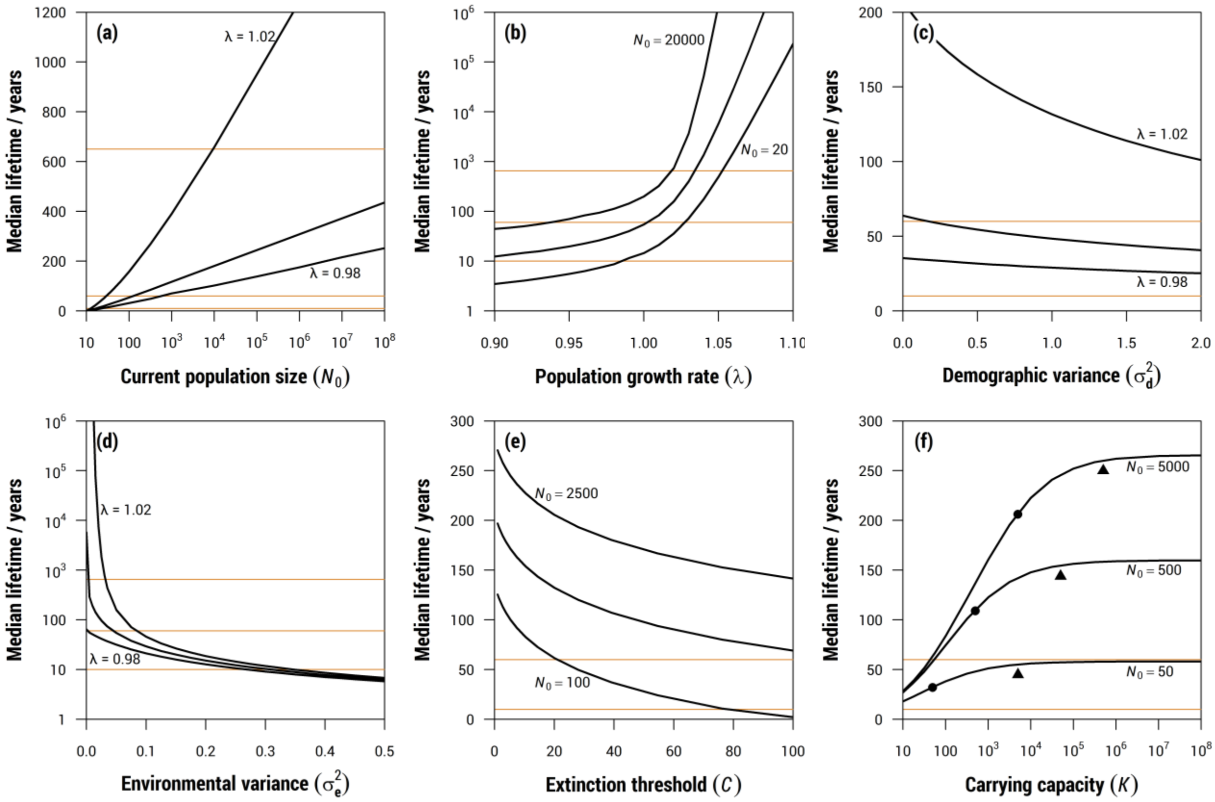

Figure X-1: Sensitivity of lifetime for the different parameters. Orange lines mark the threshold values of criterion A. **(a)** Median lifetime increases with increasing population size (N_0). Shown for three different population growth rates (λ = 0.98, 1.00, 1.02; other parameters: σ_d^2 = 0.5, σ_e^2 = 0.05, C = 10, K = 100 · N_0). Note that the *x*-axis is on log- scale. **(b)** Median lifetime increases with increasing population growth rate (λ). Shown for three different population sizes (N_0 = 20, 100, 20 000; other parameters: σ_d^2 = 0.5, σ_e^2 = 0.05, C = 10, K = 100 · N_0). Note that the *y*-axis is on log-scale. **(c)** Median lifetime decreases with increasing demographic variance (σ_d^2). Shown for three different population growth rates (λ = 0.98, 1.00, 1.02; other parameters: N_0 = 100, σ_e^2 = 0.05, C = 10, K = 10 000). **(d)** Median lifetime decreases with increasing environmental variance (σ_e^2). Shown for three different growth rates (λ = 0.98; 1.00; 1.02; other parameters: N_0 = 100; σ_d^2 = 0.5; C = 10; K = 10 000). Note that the *y*-axis is on log-scale. **(e)** Median lifetime decreases with increasing quasi-extinction threshold (C). Shown for three different population sizes (N_0 = 100, 500, 2500; other parameters: λ = 1.01, σ_d^2 = 0.5, σ_e^2 = 0.05, C = 10, K = 100 · N_0). **(f)** Median lifetime increases with increasing carrying capacity (K). Shown for three different population sizes (N_0 = 50, 500, 5000; other parameters: λ = 1.01, σ_d^2 = 0.5, σ_e^2 = 0.05, C = 10). If carrying capacity can be assumed to be at least 100 times population size (arrow heads), its precise value is of negligible significance. The dots mark situations where K = N_0. Note that the *y*-axis is on logarithmic scale.

Documentation and definitions

A population's expected lifetime is the *mean* estimated time to extinction (averaged over the probability distribution of times to extinction), taking demographic and environmental stochasticity into account. It is estimated using the following equations:

$$T_{\text{ext}} = 2\int_C^{N_0} s(x) \int_x^{\infty} \frac{1}{s(N)V(N)}\, dN\, dx\,, \tag{1}$$

where

$$s(N) = e^{-2\int_C^N M(x)/V(x)\,dx}\,, \tag{2}$$

$$M(N) = (\lambda-1)N\left[1-\left(\tfrac{N}{K}\right)^{\theta}\right], \tag{3}$$

$$V(N) = \sigma_d^2 N + \sigma_e^2 N^2 + 2\rho\sigma_e\sigma_{\ln K}\tfrac{\lambda-1}{K}N^3 + \left(e^{\sigma_{\ln K}^2}-1\right)\left(\tfrac{\lambda-1}{K}\right)^2 N^4\,. \tag{4}$$

See Leigh (1981) for the derivation of these equations. For their application, see Lande et al. (2003:38–40).

If environmental variance can be assumed to due to the occurrence of disaster years alone, growth rate and environmental variance can be estimated using the following equations (based on a 50-year period and with $n := n_{\text{dis}}$; $p := p_{\text{dis}}$; $\lambda :=$ mean growth rate in a non-disaster year):

$$\lambda' = \lambda(1-p)^{n/50}\,, \tag{5}$$

$$\sigma_e^2 = \frac{n}{49}p^2\lambda^2\left(1-\frac{n}{50}\right). \tag{6}$$

Derivation of equation 6 (where μ is the arithmetic mean annual growth rate, i.e.
$\mu = \frac{1}{50}\sum_{i=1}^{50}\lambda_i = \frac{1}{50}\left[(50-n)\lambda + n\lambda(1-p)\right] = \lambda\left[1-\frac{np}{50}\right]$):

$$\begin{aligned}
\sigma_e^2 &= \tfrac{1}{49}\sum_{i=1}^{50}(\mu-\lambda_i)^2 \\
&= \tfrac{1}{49}\left[(50-n)(\mu-\lambda)^2 + n\left(\mu-\lambda(1-p)\right)^2\right] \\
&= \tfrac{1}{49}\left[50(\mu-\lambda)^2 + 2np\lambda(\mu-\lambda) + np^2\lambda^2\right] \\
&= \tfrac{1}{49}\left[\tfrac{1}{50}n^2p^2\lambda^2 - \tfrac{2}{50}n^2p^2\lambda^2 + np^2\lambda^2\right] \\
&= \tfrac{n}{49}p^2\lambda^2\left(1-\tfrac{n}{50}\right).
\end{aligned}$$

XI. R-script for estimating expansion speed

What follows, are instructions for the **R** function EXPANSION. The program estimates the expansion speed of a population based on a spatio-temporal dataset of occurrences. Estimates of expansion speed enter the risk assessment of alien species via criterion B on the invasion axis.

The script was written by Hanno Sandvik (Centre for Biodiversity Dynamics, Norwegian University of Science and Technology). Its current version is 2.4 (as of April 2017).

These instructions are also available online (http://www.evol.no/hanno/17/expand.htm). When updated versions are released, they will be available at that URL.

Introduction and installation

The **R** script does not require any previous knowledge of **R**, but presupposed that **R** is installed on the computer. Here is a step-by-step instruction:

- **R** is an open software package that can be downloaded for free at http://www.r-project.org. Please follow the instructions on that site to install the package.
- After you have installed and started **R**, the expansion script can be loaded in one of two ways:
  - write `load(url("http://www.evol.no/hanno/17/expand.rtx"))` directly in your **R** pane (this requires your computer to be online); or
  - use your browser to navigate to http://www.evol.no/hanno/17/expand.rtx and save this file to your hard disk; later, write `load("...")` in your **R** pane, where "..." specifies the file location [for example, `load("c:/aliens/expand.rtx")`; this requires your computer to be online only when downloading the file for the first time, whereupon it can be loaded locally from your computer].
- Now you can run the script by writing `expansion(...)`, where "..." represents the parameters, which are explained in detail below.

Please note that this **R**-script is not part of any **R** package. Therefore, no **R** help will be available for this function. Please refer to these instructions instead.

The program requires a dataset containing the spatio-temporal information about the observed occurrences of the population. The dataset is specified using the `data` parameter. A program call thus has the form `expansion(data=...)`, where "..." may be any of the following three objects:

1) a *character string* specifying the location of a data file;
2) a *data frame*;
3) a *matrix*.

If you are an **R** beginner, you should choose the first option (as the two latter methods presuppose that your data have already been read to **R**). The formatting required for the data file according to option 1 is explained below. All three options require that the data are organised into columns that are named precisely as specified in the following paragraphs.

- One column has to contain years and to have the name `t`. Years have to be integers.
- The geographic positions of observations can be specified using one to six columns, depending on the coordinate system used:

Coordinate systems

Positions of observed occurrences may be specified in one of five different formats, using one of three different coordinate systems:

- Latitude and longitude
  - (1) `lat` *and* `lon` *or*
  - (2) `lat` *and* `lam` *and* `las` *and* `lon` *and* `lom` *and* `los`
- MGRS coordinates (Military Grid Reference System)
  - (3) `mgrs` *or*
  - (4) `zone` *and* `band` *and* `id` *and* `east` *and* `north`
- UTM coordinates (Universal Transverse Mercator)
  - (5) `zone` *and* `east` *and* `north`

where the variable names have the following meaning and formatting:

`lat` Latitude (degrees) – specified as an integer or real number between –90 (= 90°S) and +90 (= 90°N).

`lam` Latitude (arcminutes) – specified as an integer or real number between 0 and 60.

`las` Latitude (arcseconds) – specified as an integer or real number between 0 and 60.
`lon` Longitude (degrees) – specified as an integer or real number between –180 (= 180°W) and +180 (= 180°E).
`lom` Longitude (arcminutes) – specified as an integer or real number between 0 and 60.
`los` Longitude (arcseconds) – specified as an integer or real number between 0 and 60.
`mgrs` MGRS coordinates – specified as a character string.
`zone` UTM zone – specified as an integer between 1 and 60.
`band` MGRS latitude band – specified as a single character between 'C' and 'X'.
`id` MGRS square identifier – specified as two characters between 'AA' and 'ZV'.
`east` Easting – specified as a number, although it can be formatted as a character string. The meaning and range of allowed values differ between UTM and MGRS.
`north` Northing – specified as a number, although it can be formatted as a character string. The meaning and range of allowed values differ between UTM and MGRS.

Example

The coordinates of Tromsø (69°39'5.0"N 18°57'19.0"E) can thus be specified in the following ways:

(1) {lat=69.65139; lon=18.95528}
(2) {lat=69; lam=39; las=5; lon=18; lom=57; los=19}
(3) {mgrs="34WDC2058828390"}
(4) {zone=34; band="W"; id="DC"; east="20588"; north="28390"}
(5) {zone=34; east=420588; north=7728390}

NB

- Please note that the MGRS system and the UTM system are sometimes confused (the former is based on the latter). However, both require different formatting. While Tromsø's *UTM* coordinates are **34 420588 7728390**, Tromsø's *MGRS* coordinates are **34WDC2058828390**.
- If the data do not follow the standards for UTM or MGRS (as appropriate), the program may misinterpret them.
- The northing of UTM coordinates uses signs in order to distinguish between the Northern (positive sign) and the Southern Hemisphere (negative sign). Positive signs may be omitted.
- Leading zeros may create trouble for northings and eastings in the MGRS system. To make sure that leading zeros do not 'disappear', please save `east` and `north` as character strings rather than numbers.
- The variable names have to follow the conventions detailed above.
- The precision of the positions does not matter (well – it may matter for the results, of course, but not for the interpretation of the coordinates).
- Different observations in one dataset may use different coordinate systems.
- If more than one coordinate system is used, UTM coordinates are ignored wherever MGRS coordinates are supplied; and MGRS coordinates are ignored wherever latitude and longitude are supplied.
- The order of observations does not matter.
- The order of columns does not matter.
- Additional columns are ignored. (Nonetheless, it might be an advantage to delete superfluous columns, because columns containing commata or apostrophes may interrupt the conversion.)

Formatting of data files

If the data are read from an external file, please follow these formatting rules:

- The data have to be organised column-wise, i.e. the file has to consist of *one column per variable* (year and for instance latitude and longitude) and *one row per observation*.
- The first row has to contain the variable names (see above for the variable names that have to be used).
- All rows have to have the same number of separators.
- Missing values are tolerated if specified by omission (‘’) or spaces (‘ ’). (Other symbols, such as ‘?’ or ‘NA’, will generate error messages.)
- Semicola (**;**) or commata (**,**) are accepted as separators between columns (i.e., between the elements of a row) – but please don't use both. Such files can be produced by all spread sheet applications. (Choose ‘save as comma delimited file’ or something similar. Usual filename extensions of such formats are ‘.CSV’ or ‘.SDV’.)
- The symbol used as separator must not occur in other places. Nor may apostrophes (**'**) be used anywhere in the data file. Please make sure to remove or replace these symbols.
- The `data` parameter is used to specify the location of the data file. The location should be specified as a character string containing the file name and complete location within quotation marks, e.g. `expansion(data="c:/aliens/data/art12.sdv")`. Please note the use of slash (**/**) instead of backslash (****).
- Periods (**.**) are accepted as decimal marks. Only if semicola (**;**) are used as separators, commata (**,**) may be used as decimal marks, too.
- Spaces between (outside) elements, and quotation marks (**"**) enclosing elements (on both sides), are tolerated.

Example:

```
t;bg;lg
2006;60.00;12,00
2006;60.24;12.76
2007;   61.53;   11.36
2008 ; 62.84 ; 10.92
2010;64.15;12,1
2010;64.84;"12.15"
```

Datasets from the Species Map Service

Datasets for estimating expansion speed can be exported from the Species Map Service (http://artskart.artsdatabanken.no/) by following these steps:

1) Search for the species of interest and make the desired selections (such as time span, geographical selection, data type etc.).
2) Choose the tab ‘ObjectInfo’.
3) Press the button ‘Export data to Excel’ at the bottom of this tab.
4) Fill in the export form and press the button ‘Export data as CSV file’.
5) Of the file generated, only three columns are needed (‘YearCollected’, ‘Longitude’ and ‘Latitude’). These need to be renamed: ‘YearCollected’ to `t`, ‘Longitude’ to `lon` and ‘Latitude’ to `lat`.
6) Delete the remaining columns. (Some of them may contain commata or semicola, which can be misinterpreted as separator symbols during import.)

The file may then be used as input dataset for EXPANSION.

Parameters

Use of the `data` parameter is explained above. The remaining parameters are optional, although `dark.fig` should be provided, and `save` and `p` can be useful. Parameters are provided separated by commata, such as `expansion(data="folder/datafil", dark.fig=10, save=TRUE)`. The following parameters are available:

`data` Spatio-temporal dataset of observations. This is the only mandatory parameter. It is explained in detail above.

`dark.fig` Dark figure assumed to apply to the last year of the dataset, provided as one or more numerical value(s). A dark figure should be provided, because this will result in more realistic estimates. If one value is provided, the script searches for the optimal dark figure in the vicinity of this value. If two values are provided [e.g., as `dark.fig=c(5,50)`], the script searches for the optimal dark figure between these two values. If more than two values are provided [e.g., as `dark.fig=c(2,3,4,5)` or `dark.fig=2:5`], the script tries out exactly the dark figures specified. The default is `dark.fig=c(1,Inf)`, i.e. all values ≥ 1.

`exact` Logical variable specifying whether the dark figure provided should be treatead as fixed. If `exact=FALSE`, the script searches in the vicinity around the value specified. If `exact=TRUE`, the script only uses the dark figure(s) specified. The default is `FALSE` if `dark.fig` is provided as a single number; but `TRUE` if `dark.fig` is two or more numbers or if `p=2`.

`p` Number or numerical vector specifying how observability is modelled. The default is `p=1`, which entails that observability is assumed to be constant. If `p=2`, two observability rates are estimated for two periods of time, where the break point is also inferred from the data. If `p` is provided as a vector of length > 100, it is interpreted as a time series containing annual values of sampling effort, starting in the year 1800.

`new.obs` Logical or numerical variable specifying whether the dataset contains new observations only. The default, `new.obs=TRUE`, implies that occurrences are reported only in the year of their first observation, and are assumed to remain in place in subsequent years. Write `new.obs=FALSE` if the dataset reports each occurrence for each year of its existence – this enables models of species that have short-lived subpopulations, or of species that are subject to eradication measures. If a species is very short-lived (e.g., its occurrences usually disappear within a year), it is better to use `new.obs=-1` (in this case, only descriptive statistics are provided; no modelling of the process is implemented yet).

`mech` [not yet implemented]

`form` [not yet implemented]

`map` Logical variable indicating whether the observations should be shown on a map. Currenly this only works for Northern Europe. The default is `map=TRUE`. To switch off map view, write `map=FALSE`.

`quiet` Logical variable that suppresses messages and warnings if `TRUE`.

`save` Logical value or text string indicating whether the data should be saved after transformation. By saving the transformed dataset, coordinates do not have to be transformed each time the script is run. If specified using a text string, the latter is interpreted as file name. The default is `save=FALSE`.

`data.out` Logical variable or letter that can change the value of the function. If `data.out=FALSE`, which is the default, the script returns expansion speed as the function value. If `data.out=TRUE` or `data.out="A"`, the value returned by the script is changed to a matrix containing the annual estimates of area of occupancy (AOO) from the expansion graph. The matrix has four columns: `year` (containing years), `point` (containing the observed AOO in a given year, i.e. the points of the graph), `blue` (containing the fitted values of the known AOO in a given year, i.e. the blue line of the graph), and `red` (containing the estimated total AOO including dark figures in a given year, i.e. the red line of the graph). If **`data.out="r"`**, the value returned is a matrix with the columns just described, which, however, contain radii rather than areas. Areas are provided in km², radii in km. Note that the value of the funcation has to be assigned to a new variable using the arrow symbol "<-", e.g. **`datapoints <- expansion(...)`**.

`gamma` Numerical variable between 0 and 1, specifying the confidence level (γ). The default is **`gamma=0.5`**, which estimates quartiles. **`gamma=0.95`** gives 95% confidence intervals.

Further parameters are available, although they may rarely be needed:
- **`R`** (the radius of the Earth in kilometres; used during estimating the extent of occurrence; the average radius of the WGS 84 reference ellipsoid is used as default, i.e. **`R=6371`**),
- **`language`** (text string which can shift from English to Norwegian output; correspondingly, the following parameters exist: **`mtall`** = **`dark.fig`**, **`eksakt`** = **`exact`**, **`ny.obs`** = **`new.obs`**, **`mek`** = **`mech`**, **`kart`** = **`map`**, **`hold.munn`** = **`quiet`**, **`lagre`** = **`save`**, and **`spraak`** = **`language`**),
- **`dist`** (text string specifying whether optimisation uses a normal or a binomial distribution),
- **`kontr1`** and **`kontr2`** (lists containing parameters that control the optimisation).

Output

Before starting the estimation itself, the script give a summary of the input data and the model assumptions (this can be turned off using the **`quiet`** parameter). The function's value (returned invisibly) is the number representing the expansion speed of the population in metres per year. The output provided on the screen consists of estimates (median plus lower and upper confidence limits) for:
- expansion speed in metres per year (m/a),
- known area of occupancy (AOO) in km²,
- estimated AOO in km² (known AOO times dark figure),
- dark figure,
- extent of occurrence (EOO) in km² (not corrected for coastlines or borders),
- first year of the expansion,
- observability rate(s).

XII. Dispersal

A few final words about dispersal (Ritter 1948:19):

Am Abend eine Sonne klar,
am Morgen ein Greis im Silberhaar.
Ein Windhauch bläst sein Leben aus,
entschweben hundert Sterne draus.
Und wo ein Sternlein zur Erden geht,
in goldenen Sonnen es aufersteht.
Heinz Ritter

(Löwenzahn)

At nightfall like a sun so fair,
next morning an old man with silver hair.
One gentle wind-breath ends his day
and carries hundred stars away.
Where one of the starlets touches the earth,
a bright golden sun is given rebirth.
(Translation by H. Sandvik)

(*Taraxacum* sect. *Ruderalia* [dandelion])

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9. Glossary

Italicised terms have entries of their own.

Abundance	Number of *individuals* (e.g., at a location or per event).
Alien species	A species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans), [this] includes any part, gametes or propagule of such species that might survive and subsequently reproduce (IUCN 2000). See section 2.1.
AlienSpeciesDatabase	A web application designed by the Norwegian Biodiversity Information Centre that archives the risk assessments of alien species and the supporting data. The AlienSpeciesDatabase has one assessment interface (https://database.artsdatabanken.no/FAB3) to which only the expert groups have access, and one public interface (http://www.artsdatabanken.no/fremmedearter) that will be online once all assessments are completed and quality-assured.
Allelopathy	Production and secretion of chemical substances by one (here: *alien*) species that reduces the growth, reproduction or survival of other (here: *native*) species.
Anthropocentric	Being focussed on human interests (such as economy, health).
Anthropogenic	Being an intended or unintended (side) effect of human activity.
Area of occupancy (AOO)	4 km^2 multiplied by the number of *occurrences*. See section 2.7.4.
Bioclimate	The totality of climatic factors that influence the distribution and population dynamics of species. Bioclimatic conditions are here described using bioclimatic zones (along a temperature gradient) and bioclimatic sections (along a humidity gradient). See Table 2 for an overview, and *NiN* for a detailed description.
Carrying capacity *(K)*	*The population size* at which density regulation balances *population growth*. See section 2.7.8.
Category	See *impact category* and *score*.
Colonised	Inhabited by, i.e. containing at least one *occurrence* of, the species.
Confidence interval	Numerical interval that contains the true value of an estimated parameter with a specified likelihood (e.g., 50%, 95%).
Contaminant	*Individuals* that are *introduced* (unintentionally) while transporting life or dead organisms or organic material; this includes, but is not restricted to, parasites (that use the transported organism as *vector*).

Corridor	Interconnections (e.g., waterways, land bridges) made by humans.
Criterion	The condition that, in conjunction with a set of *threshold values*, determines the risk *score* of an *alien species*. There are three criteria that determine the *invasion potential* (A–C) and six criteria that determine the *ecological effect* (D–I).
Dark figure	Factor by which the known number/area has to be multiplied in order to obtain the estimated total number/area (total = known × dark figure). See section 2.9.3.
Delimitation	(Here:) historical, geographic, ecological and taxonomic criteria that demarcate the subset of *alien species* that are to be risk-assessed (but without narrowing down the definition of *alien species*).
Demographic variance	The magnitude of random variation in the survival and reproduction of *individuals* (demographic stochasticity). See section 5.1.1.
Dispersal	Ways of *expansion* (active or passive) that do **not** involve human activity. (Wind dispersal of seeds, migration of animals, etc.)
Displacement	Reduction by at least 1% of the *area of occupancy* **or** *extent of occurrence* of a *native species* due to *interactions* with an *alien species*.
Distance effect	*Ecological effect* of a *production species* that extends beyond the *production area* of the species (even if the species does not leave this area). See section 2.6.3.
Door knocker	*Alien species* that is not currently *established* in Norway, but is likely to do so within 50 years. See section 2.5.
Ecological effect	Consequences that the presence of a species has for the biotic and abiotic environment, including negative *interactions* with *native species* (competition, predation, parasitism etc.), genetic contamination of *native species* (*introgression*) and *state changes* in *nature types*.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (CBD 1992)
Ecosystem services	Direct and indirect benefits to human well-being obtained from *ecosystems*. See Appendix VII.
Effect	See *ecological effect*.
Entry	Intentional import or unintentional transport of a species from abroad either to indoor environments (e.g. shops, private homes, warehouses) or to the species's *production area*. See section 3.3.
Environmental variance	The magnitude of random environmental variation that affects all *individuals* of a population simultaneously (environmental stochasticity). See section 5.1.1.
EOO	See *extent of occurrence*.

Escape	*Introduction* caused by an alien species unintendedly leaving the confined area (*production area*, breeding, cultivation, farming, garden, terrarium etc.) to which it intentionally had been transported.
Establishment	Production of *viable offspring* outdoors and without human manage-ment. See section 2.4.
Expansion	Increase in the *area of occupancy*, irrespective of the mechanism involved (*introduction/dispersal*, *anthropogenic*/natural, active/passive). See section 5.1.2.
Expansion speed	The annual increase in the *area of occupancy* (measured as the increase in radius, i.e. in metres per year). See section 5.1.2.
Expert judgement	A judgement that is based on personal expertise and discretion, yet documented. This documentation does not have to provide a precise numerical value, but may consist in substantiating that the value lies between two specified *threshold values*. (Expert judgements are thus subjective, but nevertheless testable.) See section 1.4. and Appendix III.
Extent of occurrence (EOO)	The area of the smallest convex polygon that can be drawn to encompass all *occurrences* of the species. See section 2.7.5.
Extinction threshold	See *quasi-extinction threshold*.
Facilitation	See *positive effect*.
Generation time	The average age of reproducing individuals (in years). See section 2.7.6.
Genet	Group of genetically identical *individuals (ramets)* that has been formed by asexual reproduction.
Growth rate	See *population growth rate*.
Habitat	The place or type of site where an organism or population naturally occurs (CBD 1992).
Heavily modified nature	*Nature types* whose defining local environmental variables according to *NiN* are 'SX' or 'XY' (see Table V-1 for a list of these types) **or** that are characterised by intense agricultural management (Halvorsen et al. 2016).
Impact	*Invasion potential* of an *alien species* multiplied by its per-locality *ecological effect*. See section 2.8.
Impact category	One of the five categories 'no known *impact*' (NK), 'low impact' (LO), 'potentially high impact' (PH), 'high impact' (HI) and 'severe impact' (SE). The impact category of an alien species is determined by the 16 possible combinations of the maximum *score* along each axis of the risk matrix (Figure 6).
Indirect effect	An *effect* exerted by species A on species B via a third (or more) species, e.g. if A increases the *abundance* of predators or parasites of B (apparent competition), or if A reduces the *abundance* of predators of predators of B (trophic cascade).

Individual	An anatomically, physiologically, behaviourally and/or reproductively autonomous organism. See section 2.7.1.
Interaction	Mutual or one-sided effect of one (here: *alien*) species on another (here: *native*) species, including predation, parasitism, competition for space, competition for food, *allelopathy* and *indirect effects*. (Neutral or positive interactions are not assessed.)
Interquartile range	The numeric interval enclosed by the lower and upper *quartile*. Synonym: 50% *confidence interval*.
Introduction	Any human activity which has the intended or unintended consequence that *individual(s)* of an *alien species* arrive in *Norwegian nature*. See section 2.1.
Introgression	Transfer of genetic material between species (e.g., by hybridisation **and** subsequent back-crossing with the *native* parent species). See section 5.2.4.
Invasion potential	Ability to succeed with *establishment* **and** *expansion*.
Invasive species	The term 'invasive species' can have different connotations (a: species having a huge *invasion potential*; b: species having severe *ecological effects*; c: *alien species*; d: a+b; e: a+c; f: b+c; g: a+b+c) and is therefore **not** used in these guidelines.
Keystone species	Species that, despite being relatively rare (in terms of biomass), can have a large effect on the abundance, distribution **or** diversity of other species (based on Power et al. 1996; see Libralato et al. 2006, Valls et al. 2015). Examples: beaver, woodpecker, top predator.
Lambda (λ)	See *population growth rate* and section 2.7.7.
Large-scale effect	An *ecological effect* that affects at least 5% of the *population size* **or** *area of occupancy* **or** *extent of occurrence* of a *native species*.
Lifetime	See *population lifetime* and section 5.1.1.
Local ecological effect	An *ecological effect* that affects less than 5% of the *population size* **and** *area of occupancy* **and** *extent of occurrence* of a native species.
Locality	A geographically or ecologically distinct area where a single threat may quickly affect all *individuals* of a species. (Global warming is not regarded as "a single threat" in this sense.)
Mature individual	*Individual* that (judging by its state, age, size etc.) is capable of reproducing sexually and/or asexually.
Median	The numerical value that divides a set of numbers or a probability distribution into two equally large parts. Synonyms: second *quartile*; 50th *percentile*.
Migrant	Regular visitor, i.e. a species that regularly visits Norwegian territories with an *abundance* that exceeds 2% of the species's global population. (Migrants are regarded as *native*, not as *alien species*.)

Moderate ecological effect	*Interaction* with *native* species that results in a decline in *population size* of at least 15% in at least one native *subpopulation* over a ten-year period, but that does **not** result in *displacement* of the native species.
Native species	Species that *occurs* in Norway and that has been *stably reproducing* in Norway by 1800, **or** that has a *stably reproducing* population in Norway that did not originate in *introduced individuals*, **or** that is a *migrant* in Norway. (Note that this definition allows for species being *alien* and native at the same time!) See section 2.2.
Nature in Norway	See *NiN*.
Nature type	A homogeneous environment, including all plant and animal life and environmental factors that operate there, or special types of natural features such as ponds, habitat islands in fields or the like, and special types of geological features (Nature Diversity Act 2009). See Appendix V. The classification and description of nature types follows *NiN*; read-listing of nature types follows Lindgaard and Henriksen (2011).
NiN	Nature in Norway (http://artsdatabanken.no/Pages/3), a system for classifying and describing all variation in nature in Norway.
Norwegian nature	Any part of Norway that is outdoors (including *heavily modified nature*) and the *native species* occurring there; for *production species*, their *production area* does **not** count as Norwegian nature. See *nature type* and sections 2.3. and 2.6.3.
Occurrence	Grid cell sized 2 km × 2 km that is inhabited by individuals of the species, and that is essential for the survival and reproduction of these individuals. See section 2.7.3.
Other nature types	*Nature types* that are **neither** *threatened* **nor** *rare* **nor** *heavily modified*.
Other species	*Native species* that are **neither** *threatened* **nor** *keystone species*.
Pathway of introduction	Forms, mechanisms, means and routes along/by which *introduction* and/or *spread* of *alien species* can happen. These pathways are categorised into six categories and several subcategories (see Appendix IV).
60th percentile	The smallest number that is greater than or equal to 60% of the values in a set or a probability distribution (accordingly for other percentages). See footnote on page 21.
Population growth rate (λ)	The (potential) mean annual increase in *population size*. See section 2.7.7.
Population lifetime	The time until the (modelled, projected or assumed) extinction of the population of a species (in years). See section 5.1.1. (The likelihood that the population goes extinct within the *median* extinction time, is 50%.)
Population size	The total number of *mature individuals* of a species (either in a specified area or, if nothing else is stated, in Norway). See section 2.7.2.

Positive effect	The effect of an *alien species* can be regarded as positive if (seen in isolation) it increases the survival or fertility of a *native species* (facilitation) or if it stabilises a *nature type*. Positive effects should be described, but do not affect the risk assessment.
Prevalence	Proportion of a population that is infected with a specific pathogen or parasite.
Production area	The confined area of *heavily modified nature* that is specifically allocated to the production of a given *production species*. See sections 2.3. and 2.6.3.
Production species	Species that is used in production of goods or services. (This includes pets, garden plants etc.) See sections 2.3. and 2.6.3.
Propagule pressure	The number of *individuals introduced*, estimated as the average *abundance* per *introduction* event multiplied by the frequency of such events.
Quartile	The smallest number that is greater than or equal to 25% (lower quartile), 50% (median) or 75% (upper quartile) of the values in a set or a probability distribution. Synonyms: 25th, 50th and 75th *percentile*, respectively.
Quasi-extinction threshold	The *population size* at which the species has no practical chance of evading extinction. See section 5.1.1.
Ramet	Part of a *genet* that constitutes an anatomically and reproductively more or less autonomous *individual*.
Rare nature type	*Nature type* that is listed as near threatened (NT) according to criterion 2 or 3 for the red-listing of nature types (Lindgaard and Henriksen 2011).
Regionally alien species	Species meeting the definition of *alien species* and the *delimitations* in section 2.6, **except** that is has at least one *native subpopulation* in Norway, too. Such species thus have both regionally native (within the species's natural *area of occupancy*) and regionally alien *sub-populations* (that are *introduced*). See section 2.6.2.
Risk	The consequences (such as magnitude, damage, cost) of an event multiplied by its probability. See section 2.9.2.
Score	The numbers 1, 2, 3 or 4 that are assigned to an alien species for each of the nine *criteria*. The species's placement along the two axes of the risk matrix (invasion axis and effect axis, see Figure 6) is determined by the highest score on each axis (and determines in its turn the *impact category* of the species).
Secondary introduction / secondary spread	*Dispersal* from populations in a neighbouring country or area, where the presence is due to intentional or unintentional *anthropogenic introduction*.
Spread	'Spread' can either denote all forms of movement of a species (this is here referred to as *expansion*) or merely 'natural' forms of spread (this is here referred to as *dispersal*).

Stably reproducing	*Established* with a *population size* of more than 20 *individuals* for a contiguous period of more than 10 years.
State change	Change in the local environmental variation, the condition or state, the species composition, or the spatial structure of a *nature type*. See p. 75.
Stowaway	Individuals that are *introduced* (unintentionally) during the transport of people, goods, bulk, vehicles or boats (**not** of plants or animals).
Subpopulation	Distinct groups (of *individuals*) between which there is little demographic or genetic exchange (< 1 successful migrant or gamete per year).
Substantial effect	*State change* in a *nature type* that corresponds in magnitude to more than a third of the levels defined for at least one variable in *NiN*'s descriptive system. See Table V-2.
Taxon	Species, group of related species or subdivision of a species. Here mainly used for taxonomic entities below species level (subspecies, varieties, cultivars, hybrids etc.).
Threatened nature type	*Nature type* that is listed as critically endangered (CR), endangered (EN) or vulnerable (VU) according to the Norwegian Red List for ecosystems and habitat types 2011 (Lindgaard and Henriksen 2011).
Threatened species	Species (potentially subspecies) that is listed as critically endangered (CR), endangered (EN) or vulnerable (VU) according to the Norwegian Red List for species 2015 (Henriksen and Hilmo 2015).
Threshold value	Numerical or verbal descriptions of *effect* sizes that separate the different *scores* for a given *criterion*.
Traditional production species	*Production species* that has been in large-scale use in Norway by 1700. (Such species are exempted from risk assessment.)
Vagrant	Irregular visitor, i.e. a species that only rarely visits Norwegian territories, **or** that does so with an *abundance* that does **not** exceed 2% of the species's global population. (Vagrants are neither regarded as *native* nor as *alien species*.)
Variance (σ^2)	Measure of the magnitude of variation around the mean of the values in a set or a probability distribution; square of the standard deviation (σ).
Vector	(Here used in its parasitological sense:) organism that transmits a parasite or disease to other organisms or areas.
Viable offspring	Fertile offspring that survives (or is very likely to be able to survive) until maturity.
Weak ecological effect	*Interaction* that will have less than *moderate* negative consequences on the *population size* of the *native species* affected.

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