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Guidance for drafting best management practices for invasive alien species

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RESEARCH INSTITUTE FOR
NATURE AND FOREST

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Abstract

As global trade and travel intensify, species are transported around the globe at an ever increasing rate. Some of these species establish themselves in new environments, and start to spread rapidly, causing ecological and socio-economic damage. These species are termed 'invasive'. Once an invasive species is established, the ongoing cost of managing the population and mitigating its impacts on ecological services are often considerable.

Government agencies and wildlife conservation groups alongside businesses and industry need to respond to the challenge of invasive species, the cost of which, both economically and environmentally, has increased dramatically in recent years. Organisations seek to manage invasive species as effectively and humanely as possible. Management strategies can include preventive actions towards new invasions, regulation of population numbers using various methods, impact mitigation and/or landscape modification. This requires a targeted approach taking into account the species- and the area-specific context (area conditions, legal framework).

This report provides a framework for writing best practices for management of invasive species (including preventive strategies, eradication, containment and control). We screened available best practices for invasive species and literature about this subject. Based on this, we here present the necessary elements of a best practice for managing invasive alien species. Where relevant, we provide information on the specific Flemish context and reasons why these aspects should be part of a best practice.

Besides the area- and species-specific context, the contents of a best practice manual are also determined by the target audience (e.g. the general public, government agencies, specific stakeholder groups such as naturalists, hunters, anglers, beekeepers, managers of nature reserves).

This report seeks to provide guidance and a general template for the drafting and writing of best practices for invasive alien species management.

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1 A guide to reading this report

A **best practice** is a technique, method of working or activity that has proved more effective than the alternatives, and can therefore serve as a guideline for addressing a problem. The idea is that with the right working method, a management project can be carried out with fewer problems, fewer unforeseen complications and better end results. This makes it important for organisations to know the best practices in their field (in this case, species management) and to compare and, if necessary, adjust their own way of working. Inherent to the definition is the notion that best practices are a snapshot of the state of the art and can be adjusted as information becomes available about new techniques and practices. The best practices of one organisation are not necessarily those for another. A proper understanding of the context, the basic requirements and the critical success factors are crucial when making management choices.

Best practices are usually drawn up within a **specific framework**. In many cases they are part of a broader exercise such as a management plan. For example, a best practice for the pricking of goose eggs and fertility reduction of geese may be part of a broader management plan for geese, including prevention of new introductions, reduction of bird numbers and habitat management. The goal of the geese management plan may in turn be habitat restoration and damage reduction on a larger scale. It follows that a best practice for managing invasive alien species contains much more information than just the description of a specific management technique.

In this report, on the basis of a **screening of existing best practices** for (invasive) species management, a checklist is compiled of items that are important when formulating best practices for managing (invasive non-native) species. The document therefore focuses on **the information to be included in the best practice and the reasons for doing so**.

Lists of sources and legislation of relevance to the current Flemish context are provided as guidelines, but we have not attempted to ensure that these are comprehensive in all cases. This information is also liable to change, as regulations are being amended all the time, information systems are being created and updated, and so on. These source lists should therefore be regarded as a snapshot, presenting the minimum sources that should be consulted when formulating best practices.

The specific content of a best practice, finally, depends on the document's **target audience**. For example, managers with prior knowledge of the species will mainly benefit from technical details of measures. A best practice for managing invasive plants for watercourse managers will have different points of emphasis (e.g. safety aspects) from a similar document intended for a wider audience. Policy-makers who are already familiar with the legislation will be less interested in the current legislative framework, and perhaps more in the relative effectiveness of measures not permitted under current legislation.

The guidance in this report makes no prior assumptions about the target audience. The elements listed here for inclusion in a best practice can therefore be regarded as the completest possible version of a best practice, intended for as wide a target audience as possible. A selection from these can be made that takes the intended target group into account.

2 Approach

We have screened existing best practices for their content. In order to start with as extensive a set of documents as possible, no selection was made in the first instance on the basis of particular taxa, geographical delimitations or other criteria.

The emphasis in our search for literature and other sources was on good practices for the prevention, eradication, management and control of invasive species. In addition, a number of sources were also consulted which deal more generally with the management of nuisance species and harmful species. A number of specific guidelines to catching animals were also included in the literature study. In addition to this desktop search for existing best practices available online, additional relevant references for the management of (invasive) species were collected via:

- the Aliens-L list server, a global mailing group on invasive alien species with 798 members which has been active since April 1994 and is run by the IUCN SSC Invasive Species Specialist Group. The list server's archives (http://listserv.utk.edu/archives/aliens-l.html) were also searched for additional material, using the search string "best practice";
- researchgate (www.researchgate.net), a social network for scientists that also allows specific questions to be asked within thematic areas;
- The European Wildlife Network (http://europeanwildlife.net/), a knowledge network for the management of mammals and birds in Europe;
- The Conservation Evidence (http://www.conservationevidence.com/) website and journal of the same name, a freely accessible website with articles written by and for conservation managers about the impact of management measures, including habitat restoration and species management methods;
- The list server of the Global Invasive Species Team (http://www.invasive.org/) of the Nature Conservancy
- Google Scholar and ISI Web of Knowledge, using the search terms "invasive species", "management", "best practice" and combinations of these.

3 Results

The online searches and enquiries yielded best practices for the following species/groups of species:

Animals

Canada goose *Branta canadensis* (Department of Conservation, 1991; FERA, 2011; Canadian Wildlife Service, 2011a,b)

Muskrat *Ondatra zibethicus* and Coypu *Myocastor coypus* (Association of Fish and Wildlife Agencies 2014; FACE, 2013c; Stuyck, 2016)

Raccoon dog *Nyctereutes procyonoides* (FACE, 2013b)

Raccoon *Procyon lotor* (Association of Fish and Wildlife Agencies, 2014)

Wild boar *Sus scrofa* (The Deer Initiative, 2009)

European pine marten *Martes martes* (FACE, 2013a)

Wild dog *Canis lupus familiaris* (Thomson & Rose, 2006)

Deer (The Deer Initiative, 2009; Mayle, 1999; National Park Service, 2006)

Fox *Vulpes vulpes* (FACE, 2013d)

Grey squirrel *Sciurus carolinensis* (Northern Ireland Squirrel Forum 2013)

Red lionfish *Pterois volitans* (Morris, 2012)

Plants

Common ragweed *Ambrosia artemisiifolia* (Bullock, 2013; Buttenschøn et al., 2010)

Knotweed *Fallopia spp*. (Environment Agency 2006; Kelly et al., 2008b)

Giant hogweed *Heracleum mantegazzianum* (Nielsen et al., 2005)

Himalayan balsam *Impatiens glandulifera* (Environment Agency, 2010; Gibson, 2014; Kelly et al., 2008a)

Common reed *Phragmites spp*. (Ontario Ministry of Natural Resources, 2011)

Rhododendron (Forestry Commission, 2008; Edwards, 2006; IUCN SSC Invasive Species Specialist Group, 2010)

Groundsel bush *Baccharis halimifolia* (Department for the Environment and Territorial Policy of the Basque Government, 2014)

Invasive plants in general (Columbia & Columbia, 2011; Perron, 2008)

Invasive aquatic plants (Environment Agency, 2010)

Aquatic invasive species (Minnesota Department of Natural Resources, 2012)

More general works

Wildlife damage (Hygnstrom et al., 1994)

4 Checklist for the preparation of best practices

On the basis of the scanned sources, we propose the following components as constituting integral parts of a best practice for managing invasive alien species. For each (sub)component, we indicate more specifically what it means and why it is important to provide this information in a best practice for dealing with invasive alien species.

4.1 Species information

4.1.1 Species name and taxonomy

Scientific name of the species and most frequently used common names. It should be borne in mind here that subspecies or hybrids can play a specific role in invasion processes (e.g. Bohemian knotweed *Fallopia x bohemica* and Townsend's cord grass *Spartina x Townsendii* are hybrids with a strongly invasive character; the Atlantic Canada goose *Branta canadensis canadensis* is invasive, unlike the Aleutian cackling goose *Branta canadensis hutchinsii*) (Abbott, 1992), so the taxonomy should be displayed as far as the relevant level.

4.1.2 Identification

A brief description of the species, with key features for reliable identification. An overview of species with which it can easily be confused and differences from these species. As well as a list of qualitative characteristics, a good description will also provide quantitative information that allows a report to be verified (e.g. size, weight). It is important to be specific when sizes are indicated (head-to-rear length, including/excluding tail) and always to indicate units with sizes/weights. Descriptions should include information on identifying different sexes and life stages (young/old/breeding) as this may provide information about the status of the population which may be of importance for management.

In addition to a description of the species, any other information that may indicate its presence is useful. For mammals, for example, it is helpful to include a description of tracks, burrows, droppings, typical damage, etc.

4.1.3 Reporting

Information about where and how observations of the species can be reported. It is important to give a range of options to make reporting as easy as possible: existing online, centralised recording platforms, but also a contact phone number or a general email or postal address can be helpful.

Reference can also be made to current initiatives regarding monitoring of the species or species group in question, to specialists in the field who can be contacted for verification of photos or evidence, or to new technologies (e.g. smartphone apps, sensors) that can help with the reporting of observations, and that can be an excellent tool for providing professionals and volunteers with a platform for rapid reporting of data (Roy et al., 2012; Tweddle et al., 2012).

4.1.4 Distribution and status

4.1.4.1 Native range

Information about the native range of the species, including the status of the species here (e.g. IUCN Red List category).

4.1.4.2 Distribution outside native range

Information on the distribution of the species outside its native range ('invasive range').
If the status of the species (alien/native) is unclear, this must also be indicated with proper references.

4.1.4.3 Pathways

Information about the pathways by which the species was introduced outside its range is essential for conducting a preventive policy. This information will become even more important in view of the new EU Regulation on the prevention and management of invasive alien species in Europe (EU, 2014; Genovesi et al., 2014). This Regulation places great emphasis on pathway regulation as a preventive tool to counter possible unintentional introductions (Communication of the European Union 2013/0307COD PE-CONS 70/14, Article 13 - Action plans on pathways).

In general terms, four categories of pathways for alien species are distinguished (Wittenberg & Cock, 2001 @ref IUCN & CBD):

- Species introduced intentionally for use as a crop or food source (cultivation), for ornamental purposes or for hunting, fishing or nature conservation purposes. A large proportion of plants and mammals were introduced into Europe by this pathway (DAISIE, 2009a; DAISIE, 2009b).
- Animals can escape from collections (pets, zoos, botanic gardens, aquariums, garden ponds and other types of collection). A good example are vertebrates that become established after (multiple) escapes from collections.
- Unintentional introductions are a very important pathway for many invertebrates in terrestrial, freshwater and marine environments. Well-known examples for marine invasions are ballast water and sessile marine or freshwater organisms which are spread on ships' hulls.
- Distribution vectors or factors that contribute to dissemination in the environment. This refers to man-made structures (railways, canals, roads, etc.) or habitat changes that allow species to spread within or into other areas.

It is often hard to distinguish between these terms. It is therefore advisable to use a standard terminology for identifying pathways of invasive species, such as the classification of Hulme et al. (2008), which also formed the basis for the internationally applied pathway classification of the Convention on Biological Diversity (https://www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf). Meanwhile, more guidance on interpreting the various CBD categories for pathways became available (Harrower et al.).

4.1.4.4 Distribution in Flanders

A short description or (link to a) distribution map showing where the species is and is not found in Flanders. For species that are not yet present but which appear on an alarm list according to risk analyses, the description can indicate which areas in Flanders are at risk of introduction. This can be estimated on the basis of – if available – niche modelling, climate matching or risk mapping. If these are not available, at least a qualitative description of the risk areas (potential map) is desirable, based on information about the pathways and ecological requirements of the species.

4.1.4.5 Invasion history in Flanders

The date of first introduction, information about the time between introduction, establishment and population explosion ('lag time'), if known, as well as how long a species has already been naturalised and established are important elements for choosing a management goal (rapid eradication, longer-term population control, population containment). Rapid elimination is, whenever possible, the best solution after prevention for dealing with biological invasions (Genovesi, 2007; Genovesi, 2011; Genovesi et al., 2010; Genovesi & Shine, 2004; Shine et al., 2008). On the other hand, the ill-considered eradication of longer-established species involves a risk of hard-to-predict cascade effects on the entire ecosystem (Bergstrom et al., 2009; Zavaleta et al., 2001).

4.1.5 Habitat

A description of the habitats in which the species occurs. This should indicate whether and when in its life cycle the species is marine, estuarine, freshwater (running/ stagnant) or terrestrial.

4.1.6 Ecology

A description of the ecology of the species (diet, foraging behaviour, reproduction, life history). The emphasis is placed on aspects that are relevant to understanding the invasiveness and impact of the species and possible management measures and their impact.

4.1.7 Impact

Most best practices examine, either briefly or in detail, the various forms of impact of the species concerned. These may include a reduction of native biodiversity due to an impact on specific native species (through predation, competition, hybridisation, or transmission of diseases or pathogens) or on ecosystems (nutrient cycles, food webs, succession). However, there may also be other forms of impact such as public health risks, blockage of water courses, water pollution, infrastructure damage or various forms of nuisance, whether perceived or otherwise. An account of the various types of impact of an invasive species is relevant to understand how the management measures described in a best practice can reduce or mitigate it.

Reference may be made to any existing risk analyses for the species (for Belgium, a number of analyses for alien species are available at http://ias.biodiversity.be/species/risk) (Vanderhoeven et al. 2015). It should be borne in mind that risk analyses are produced for a specific risk assessment area, and the conclusions cannot simply be extrapolated to other regional or local situations. Documents from the same biogeographical region (the UK, the Netherlands, parts of France and Germany) are usually useful, however, and certainly provide much interesting information.

4.2 Policy and regulations

No best practice omits to discuss legislation that is relevant to management.

For some species, there are specific legal requirements that must be met before management measures are possible.

In addition, lists are often available of prohibited methods of capture and trapping, and some technical options for combating the species (e.g. use of pesticides, biocides, biological control) are only usable under certain conditions (e.g. not permitted by law in all areas). For the prevention and management of invasive alien species and the basic requirements in Flanders, the following list of legislation is the minimum that is relevant:

- Positive list of mammals (Royal Decree of 16 July 2009 establishing the list of mammals which may not be kept for production purposes): list of animals that may be kept by private individuals without a licence. If a mammal does not appear on this list, it therefore may not be kept as a pet. For the species that do not appear on this permitted list, there is also a ban on advertising for sale under Art. 11bis of the Law of 14 August 1986 on the protection and welfare of animals;
- Royal Decree of 10 August 2005 on combating organisms harmful to plants and plant products: this transposition of the Phytosanitary Directive (2000/29/EC) deals with protective measures against the introduction and spread in the EU of organisms harmful to plants and plant products;
- The Hunting Decree and the Hunting Season Commencement, Hunting Conditions and Hunting Administration Order;
- The Wildlife Order;
- The Nature Decree and Species Order (Flemish Government Order on Species Protection and Management of 15 May 2009);
- The River Fisheries Law (Law of 1/7/1954 on River Fisheries);
- The Animal Welfare Law (Law of 14 August 1986 on the Protection and Welfare of Animals): provisions on the killing of animals as a control measure (Art. 15);
- The Marine Environment Protection Law (Marine Environment Law 1999): prohibition on the introduction of non-native species into the maritime areas under the jurisdiction of Belgium;
- The Decree and Order on Sustainable Use of Pesticides (from 1 January 2015 onwards): regulates the use of pesticides in different areas and possible exceptions for the control of invasive species; www.zonderisgezonder.be;
- The EU regulation 1143/2014 on the prevention and management of invasive alien species (from 1 January 2015 onwards) and its implementing regulations (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm);

- The Leghold Trap Regulation prohibiting the use of leghold traps in the European Union, the agreement on international humane trapping standards and the proposal for Directive on international humane trapping standards.

4.3 Objectives, measures and management strategies

4.3.1 Objectives

When drawing up a code of best practice (CBP), it is advisable to indicate clearly the objective that is sought with the various measures.
An attempt should be made to distinguish between the final objective (*fundamental objectives*) and the objectives that relate to intermediate steps or subsidiary goals (*means objectives*) that one wishes to achieve with a view to the higher-level fundamental objectives (Gregory et al., 2012; Runge et al., 2013). As far as invasive alien species are concerned, the definition of the Species Order (Article 1,4°) emphasises that the ultimate objective of the IAS approach is to "*minimise the negative impact on native biodiversity and its ability to meet human needs*".

Subsidiary objectives towards the achievement of this main objective could include preventing the introduction, establishment or further spread of an invasive species in Flanders, or taking measures to minimise the potential impact of the species on biodiversity or its capacity to meet human needs. Ways to achieve these subsidiary objectives could include the control of introduction pathways, countering illegal introductions, awareness-raising campaigns, legislative action, trapping and/or killing animals, local damage prevention measures and so on.

The various objectives, subsidiary objectives and measures together constitute a hierarchical group in which both the determination of the concrete objectives and the choice between possible measures are species-, context- and scale-specific (Figure 1).

It also goes without saying that decisions at the level of a specific area, municipality or region always depend on choices and decisions at a higher level (Flanders, Belgium, Europe). **Therefore, when a CBP is being drawn up, there should be a clear indication of which choices (objectives) have already been determined for a species – and by whom and why – as well as an indication of the degree of freedom of the target audience of a CBP, i.e. the choices actors are able to make themselves.**

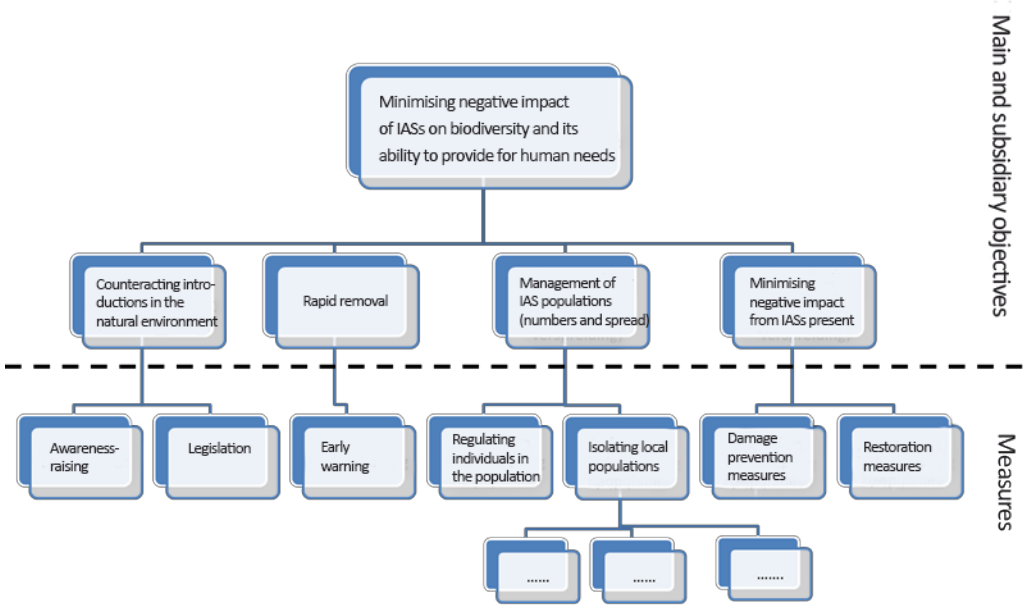

Figure 1: Hierarchy of main and subsidiary objectives and measures relating to the issues of invasive alien species and the response to them.

Under the European Regulation, a first European list is expected by the end of 2016 (Genovesi et al., 2014) based on risk analyses using a uniform method (Roy et al., 2014). For the organisms on this list, the subsidiary objectives have already been set by Europe. For countries where the species are not yet present, the different regions will have to devise a strategy that counteracts the introduction and establishment of the species through pathway action plans; if a species is already present in a region, the region must ensure that the species does not increase further in range or number. The national/regional management objectives (eradication, containment, control) set for Union List species represent objectives already determined and should be taken into account when drafting a CBP.

Generally speaking, as far as the subsidiary objectives (see above) are concerned, it is assumed for invasive alien species that preventing introductions by means of awareness-raising and legislation is the most efficient approach, followed by early warning and rapid removal . Population control and preventing the species from spreading any further form the final step (Figure 1), when the first two options cannot be implemented due to circumstances or policy choices (e.g. trade-offs with other objectives or budget priorities). The taking of measures to minimise the impact of the invasive alien species – once it is present – on biodiversity is likewise only applicable if attempts to prevent the introduction or establishment of the species have failed.

Finally, the outcome of a decision-making exercise may also be that, because of a low risk estimate, disproportionately high costs, serious unwanted side effects, local conditions or other prioritisation considerations, a (provisional) decision is made to do nothing and simply monitor the situation. This is referred to as the 'zero management' option. Unlike with conservation decisions, where doing nothing may in itself represent the implementation of an objective – namely that of allowing spontaneous processes to take their course in nature without human intervention – zero management in the context of IAS species is mostly the result of a weighing up of costs and benefits, the urgency of intervention, possible side effects and any other arguments that play a part in prioritising invasive alien species to be tackled (e.g. Booy 2015; Booy et al. 2017).

The terms and concepts used in Figure 2 in practice form a continuum and are hard to separate clearly. For example, the regulation of the number of animals (population control) may form part of the isolation of a population, and a clear line cannot be drawn between early warning and removal and the eradication of a new local population (management) (e.g. Chinese muntjac in Flanders).

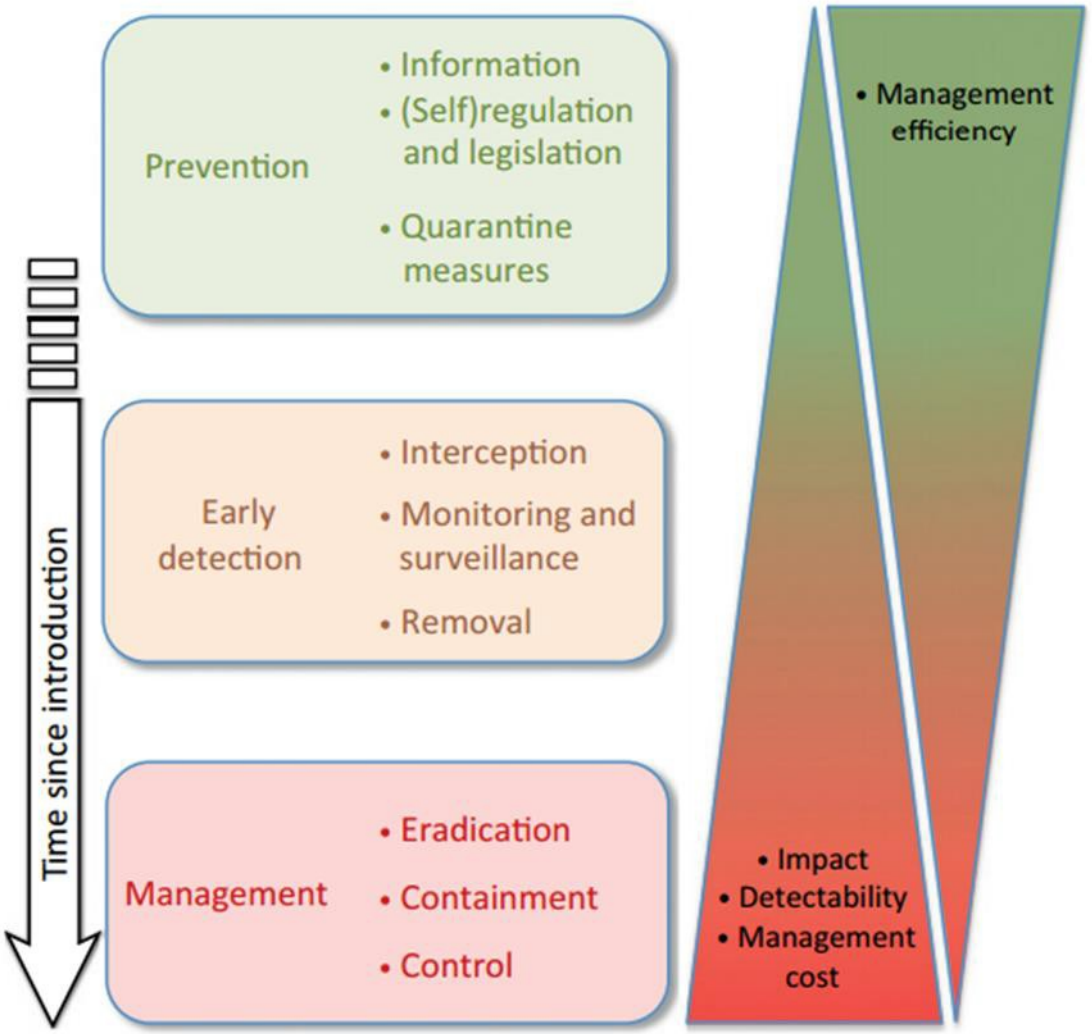

Figure 2: Strategy against invasive alien species. The optimal strategy evolves over time following introduction. The longer the time since introduction, the more the efficiency of management decreases and management costs increase (Simberloff et al., 2012).

4.3.2 Management measures

Once the subsidiary objective(s) has/have been determined, the concrete measures or tools to be used must be chosen. This choice again depends on the local context and any legal or social requirements.

For the administrator or user of the CBP to be able to make a substantiated choice between the possible measures, it is necessary to discuss the pros and cons and the basic requirements for each measure clearly in the CBP (see 4.7).

4.3.3 Management strategy

For some species, a coordinated action plan with a mix of management measures will be desirable. Zero management, eradication, damage control and population control may be differentiated at local level depending on the geographical area, the intensity of damage or the presence of important natural values (e.g. management in Special Protection Areas where the species has an impact on conservation status). One example is New Zealand pygmyweed *Crassula helmsii*, a species now found across Flanders, but for which few cost-effective management measures are currently known (Adriaens et al., 2010). For this species, a choice may be made in favour of zero management or active management depending on the invasion status and the presence of specific natural values.

The management strategy consists of all measures and actions as well as the description of the time and place where they will be deployed in order to achieve the various subsidiary objectives.

The management strategy as such is not part of the CBP, as it is case- and scale-specific, and must be determined for each specific situation on the basis of the information and assessment frameworks from the CBP.

4.3.4 Assessment framework for choice of most appropriate management measure

Many best practices contain decision trees and assessment frameworks for both the choice of management objective (eradication, containment, population control), and the control measures specifically applicable under these options. An example of this is the best practice for the management of the pumpkinseed sunfish (van Delft et al., 2013) or the decision support framework for management of Carolina fanwort *Cabomba caroliniana* (Scheers et al. 2016); these use relatively simple decision trees to allow users to quickly work through the research and control regulations, as well as introducing a 'management key' that can serve as a guideline if a decision has to be made about whether to take control measures. This key includes prevention, migration limitation and control options (Figure 3).

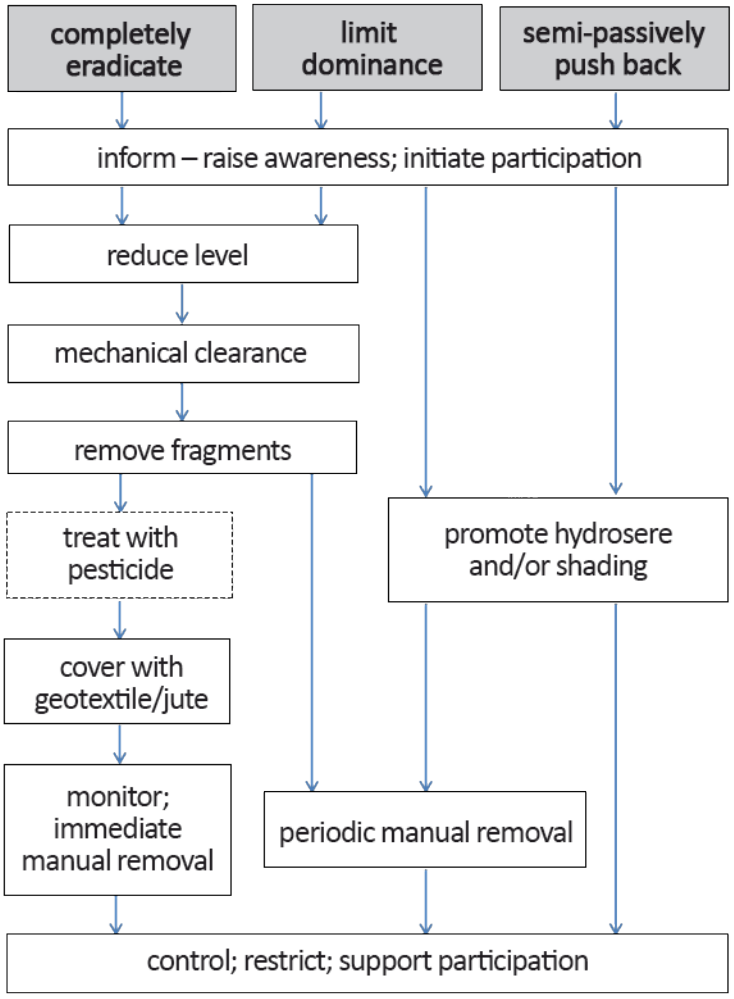

Figure 3: Example of a decision tree for determining the appropriate management option for combating larger populations of curly waterweed *Lagarosiphon major* (Denys et al., 2014).

4.4 Preventive measures to reduce the risk of introductions (step 1: prevention)

4.4.1 Communication

Communication of damage risks often forms an essential component of a (preventive) management strategy for invasive species, as well as being a general point to consider for all components. Communication is intended to inform and raise the awareness of all users and potential users of an area, the main aims being to reduce the chances of further spread and reintroduction, increase appreciation of the need to combat introductions and the social costs of those introductions, generate understanding for the interventions and their consequences, and build support.

Some general guidelines on communicating the risks of potentially invasive species and raising awareness of this issue on the basis of experiences in Flanders can be found in Invexo (2013). Van Ham et al. (2013) also discuss a series of case studies in which this is covered in detail.

4.4.2 Biosecurity

Biosecurity consists of all activities aimed at preventing introductions of new species into a particular region, but may also be part of a strategy for controlling a population already present. In this latter case, it is classified under containment (limiting species spread e.g. by installing barriers to dispersal) and the prevention of further spread e.g. by taking measures to reduce dispersal rates such as density reduction (4.6).

Biosecurity is an integral part of controlling or limiting the impact of invasive species (Perrings et al., 2005; Simberloff et al., 2012; Wittenberg & Cock, 2001); enhancing biosecurity awareness is regarded as one of the key action points in the management of biological invasions in Europe (Caffrey et al., 2014). Routine application of security regulations may minimise new introductions of unwanted species, pathogens, etc. For this to happen, they must be applied consistently at all levels, from government to individual (Caffrey et al., 2014; Ireland, 2014).

One particular point for consideration is activities to combat alien species that are outsourced and carried out by an external organisation. The inclusion of the necessary biosecurity measures (e.g. cleaning a crane before/after removal of invasive aquatic plants) in standard or specific tender specifications is essential.

Examples of activities that pose a risk of the further spread of propagules of invasive species include:

- field work being done by people in different areas;
- field equipment being exchanged between areas;
- work being done in vulnerable habitats (upper courses of rivers, springs, pools, watercourses, other water types), such as water-based research and activities;
- activities involving collecting and handling of plants and animals;
- specific activities (research, control) for certain species or species groups (amphibians, invasive plant species, macro-invertebrates, alien fauna, etc.);
- activities in places where fragments of invasive plants may be accumulated (e.g. New Zealand pygmyweed, watermilfoil, waterweed);
- reintroductions and translocations represent a risk of the unintended spreading of non-target species or pathogens (e.g. fish parasites, pathogens and diseases).

The use of biosecurity measures for invasive species is still in its infancy in Flanders, and its effective implementation often requires specialised knowledge about the effectiveness of measures and products, as well as thorough technical knowledge about their application (Barbour et al., 2013). However, a number of measures are simple and effective, for example:

- visual inspection and cleaning of used material;
- drying of nets and other collection material;
- cleaning of footwear and material to prevent the spread of propagules of invasive plant species. Research into the propagules of alien plants in the polar region (Spitsbergen) showed, for example, that the soles of shoes are an important vector of new plant seeds (Ware et al., 2012);

- carrying out activities in watercourses in a downstream direction to prevent invasive species from spreading upstream.

An example of a specific biosecurity approach applied in Flanders is the guidelines for INBO fieldwork (Figure 4) and ANB employees (http://www.natuurenbos.be/~/media/files/themas/soortenbescherming/ziekten/bioveiligheid%20bd%20bs%20r%20amfibie.pdf) with regard to preventing the spread of *Batrachochytrium salamandrivorans* (*Bsal*), which poses a threat to European salamanders (Martel et al., 2014). The use of simple disinfection measures (use of Virkon S) for clothing and field materials, taking a second pair of boots and specific guidelines on what to do if dead salamanders are found can be effective in reducing the spread of the fungus. Such measures also exist for other animal diseases, such as the preventive measures for fauna managers in contact with large game species, including the prevention of the spread of African swine fever among wild boar in Flanders.

Figure 4: Application of the biosecurity protocol to prevent the spread of the fungus *Batrachochytrium salamandrivorans* (*Bsal*), which poses a threat to salamanders.

4.4.3 Control of pathways

Preventing introductions is often considered at the level of individual species. However, identifying important pathways of problematic species is a more powerful way to reduce the risk of invasions of multiple species at the same time (Hulme et al. 2008, Hulme 2009, Essl et al. 2015). These efforts are usually concentrated at entry points and in areas at risk of introductions. The EU regulation also places a strong emphasis on regulating pathways as a tool for the prevention of unintentional introductions, and requires Member States to identify priority pathways for invasive alien species and develop action plans for their control (see 4.1.4.3). An overview of relevant pathways in Flanders and potential measures to reduce their risk levels is available in Adriaens (2016) and more comprehensive pathway analysis and action plans for Belgium are underway.

Possibilities for preventing further invasions linked to specific pathways include:

- Establishing a licensing system, requiring the justification of intentional introductions, cf. the current regulations on the introduction of organisms for biological control, which is subject to authorisation preceded by risk analysis;
- Interceptions of introduced species on the basis of regulations, enforced by means of inspections, quarantine and border controls. This requires thorough risk analysis that complies with World Trade Organization (WTO) standards (cf. Roy et al. 2014);
- The treatment of material that may be contaminated with alien species, e.g. preventive heat treatment of timber in containers before global transport or phytosanitary measures for live plant material;
- For the pathway 'natural spread from neighbouring populations', monitoring with a view to early detection and rapid response is important (see 4.5).

Hulme et al. (2008) present a conceptual framework for concrete control actions linked to specific pathways. This requires considerable expertise (Essl et al. 2015); if known and available, the possibilities for control of the identified pathways should form an integral part of a best practice.

4.5 Early warning & rapid response (step 2: early detection)

An early warning system (EWS) involves the provision of timely and effective information, to and by competent institutions, making it possible to take action to avoid or reduce risks, and to prepare for an effective response (UNEP, 2012). After prevention, early warning and rapid response (EWRR) is the most effective and efficient and least harmful way of controlling invasive species (Pluess et al., 2012a; Pluess et al., 2012b; Simberloff et al., 2012; Wittenberg & Cock, 2001).

A comprehensive early warning system for invasive species consists of a number of elements. It is an operational framework designed to respond to biological invasions through a coordinated system of surveillance, determination of incoming species, assessment of risks associated with biological invasions, circulation of information about the introduction, including reporting to the competent authorities and, finally, planning and execution of a suitable response (Genovesi et al., 2010a).

In the context of a best practice, early warning for prevention purposes can focus on providing information that enables rapid detection: organising targeted surveillance and the methods for this, description of inventory methods, etc.

It is definitely important to mention any existing reporting tools. The form of such a reporting tool may vary, from a simple email address (e.g. the address exoten@oost-vlaanderen.be for reporting alien plant species in watercourses in East Flanders) to a specific smartphone application (Adriaens et al. 2015) or a recording website (e.g. waarnemingen.be, http://biodiversite.wallonie.be/fr/invasives.html?IDC=5632). In 2011, the Agency for Nature and Forest (ANB) and the Research Institute for Nature and Forest (INBO) started up a pilot project concerning early warning for invasive alien species. For a number of notorious invasive species, ANB and INBO launched, in collaboration with the Brussels-Capital Region and Natagora, an early warning system via the website waarnemingen.be managed by Natuurpunt Studie (http://waarnemingen.be/invasive_alert_view.php).
This reporting point can be used to report observations and consult information sheets about the identification of problem species.

Also, as a field manager or intervention worker, you have the option of receiving an alert in your mailbox when new reports of invasive species come in. The pilot phase ran from March to November 2012 for established, emerging and alarm list alien species. The intention was to look at how such a system for reporting species present in low numbers can work, to make alien species more prominent in the collection of observations by volunteers (citizen science), and streamline the entire process, from observation and reporting to intervention. The system on waarnemingen.be is already being used for various rapid response projects in Flanders, for example to combat invasive aquatic plants, the ruddy duck, Pallas's squirrel, the American bullfrog, giant hogweed and Chinese muntjac (Adriaens et al. 2015b). It should therefore be mentioned in every best practice.

Figure 5: Screenshot of the *That'sInvasive!* Smartphone app for reporting invasive species.

New technologies, such as smartphone apps (Figure 5) can be a useful tool for the practical organisation and streamlining of rapid detection and reporting of invasive alien species (Teacher et al. 2013, Van Valkenburg & Odé 2014, Adriaens 2015, Adriaens et al. 2015). In this way, volunteers can also be involved in data collection, which clearly helps to raise awareness (Scyphers et al. 2014, Adriaens et al. 2015). Data should be made public through inclusion in open data repositories (e.g. gbif) so that they are available for reporting, research and other applications, and also stored and made accessible permanently (Groom et al. 2015).

4.6 Measures to prevent the further spread of a species or counteract its impact (step 3: management).

4.6.1 Eradication

Eradication usually means the complete removal of all individuals from a population by means of a time limited campaign (Bomford and O'brien 1995). An example is the eradication of Pallas's squirrel *Callosciurus erythraeus* in west Flanders (Adriaens et al. 2015). The definition of eradication in the context of biological invasions is sometimes expanded to include reducing the number of animals in a population to a critical level, under which there is a realistic chance of stochastic effects (Allee effects) that will lead to the extinction of the local population (Liebhold & Bascompte, 2003; Taylor & Hastings, 2005). Also, sometimes the term eradication actually rather refers to removal i.e. the complete removal of a species from an area but with ongoing effort to maintain the area as clear because of the permanent risk of recolonisation. The current muskrat control program in Flanders represent an example (Verbeylen & Stuyck 2002; Stuyck 2016).

When successful, eradication is more cost-effective than population control, which requires continuous spending over a long period of time (Genovesi et al., 2010a; Panzacchi et al., 2007). However, this measure is generally only considered feasible in the early stages of invasion when populations are still small and localised, or when the area in which they occur is of a manageable size and good, cost-effective methods of removal exist (Pluess et al., 2012a; Pluess et al., 2012b).

Waiting for the impact of an introduction to become clear involves the risk that irreversible changes may already have occurred in the ecosystem. Another important argument in favour of rapid removal is that, soon after introduction, any unexpected effects associated with the removal of longer-established species from ecosystems will be limited. These effects mainly occur when species have been established for some time and have come to provide lost ecosystem functions or services. Examples include the loss of a source of food for native species

(Román, 2011), the loss of bioremediation (e.g. filtering) (MacIsaac et al., 1999), the facilitation of other invasive alien species in the same environment (van Kleef et al., 2008) or compensatory increases in other invasive alien species following the removal of a particular species (Hulme & Bremner, 2006), the release of predators (Courchamp et al., 1999) or other unexpected changes in components of the ecosystem.

In other words, rapid removal is ecologically less risky (Adriaens et al., 2015; Caut et al., 2009; Simberloff et al., 2012). However, large-scale eradication actions require a good feasibility study (including legal, technical and financial considerations), support from all competent authorities and relevant stakeholder groups, a clear action plan and procedure, responsible methods and proper coordination between the different parties involved. Eradication is also best considered in the context of the entire ecosystem (Zavaleta et al., 2001).

4.6.2 Containment (prevention of further spread) of populations

Containment is taken to mean stopping or trying to stop a biological invasion locally and preventing its further spread, for example by creating migration barriers or removing/combating populations in the invasion area (Burnett et al., 2006). A best practice should discuss the possible options for containing (isolating, preventing the further spread of) populations. Account should be taken of available information on mobility, dispersal and terrain use of the species in the local context. Possibilities include, for example, migration restrictions through the setting up of physical dispersal barriers (game fences, amphibian screens, grids, locks, retaining walls, etc.) or other migration-limiting interventions in the habitat of the species (raising paths and quays, preventing water flow, density reduction).

The application of biosecurity measures (see 4.4.2) is another important measure for isolating/containing invasions.

4.6.3 Population control

By this we mean regulating/controlling the number of individuals in the population in the longer term, i.e. stopping population growth and/or reducing the number of individuals in a population.
Population management is applied to invasive alien species if elimination is not (or no longer) a realistic option. The counteracting of population growth or reduction of the population present can be carried out in practice by means of measures that affect one of the four elements of the BIDE equation (where N represents the number of individuals in the population) (Caswell, 2001):

dN/dt=B(irth)+I(mmigration)-D(eaths)-E(migration)

The local trapping and removal of animals that are not killed is ecologically equivalent to increasing emigration. However, moving animals or plants to other areas leads to the introduction of unwanted alien species in another area, and therefore does not usually constitute a realistic management measure.

As well as direct measures (trapping, killing, immunosterilisation, etc.) that have a direct impact on the population growth rate, measures affecting nesting opportunities or food supply may also result in lower reproduction and hence lower population growth.

Active biological management can also be used as a control measure to reduce (or even eradicate) alien populations. A good example of this in aquatic ecosystems is the introduction of native predators against the American bullfrog *Lithobates catesbeianus* (Louette, 2012) or the topmouth gudgeon *Pseudorasbora parva* (Lemmens et al., 2014).

Successful implementation of population control measures requires the setting of clear goals which are supported by those carrying out the measures, and possibly central coordination. Proper monitoring of the populations and of the implementation of the measures and their results is indispensable, in order to allow regular evaluation and adjustment of the management activity when required (Williams et al., 2002).

4.6.4 Damage prevention and mitigation measures

Damage prevention and mitigation measures are all measures that can be taken to minimise negative impacts of an alien population that is present.

These might include measures that make vulnerable infrastructures, plants or indigenous species inaccessible to alien species or protect them against these species (fencing, prohibiting access to certain areas). Other examples include measures to minimise competition with native species

from alien species for food or nesting opportunities.

With regard to damage problems, the government makes a distinction between wildlife damage and damage by protected species. The Species Damage Order (2009) determines the conditions under which compensation may be obtained for damage incurred. This Flemish government order provides that compensation for damage caused by protected species or wildlife can only be paid if all reasonable measures have been taken to prevent the damage. The code of best practice regarding measures to prevent fauna damage provides the framework for mammals and birds (Roggeman, 2014).

4.6.5 Increasing the resilience of ecosystems

Although less frequently used, certain measures at the level of habitats (habitat management) can make them more resilient against invasions. One good example is active biological management in aquatic ecosystems through the introduction of native predators of the American bullfrog (Louette, 2012) or topmouth gudgeon (Lemmens et al., 2014) and the restoration of balance to the aquatic ecosystem by their introduction. The presence of certain fish species also affects the success of invasive species such as topmouth gudgeon (Britton, 2012). General guidelines for this can be found in the manuals for managers of Special Protection Areas (Van Uytvanck & De Blust, 2012; Van Uytvanck & Goethals, 2014). If available, such restoration measures can form part of a best practice guide for conservationists.

4.7 Description of management measures

Each management measure has its own purpose and specific character, possible side effects, efficiency and effectiveness and other features. To allow a comparison between a set of possible measures in light of a specific subsidiary objective and to choose the most suitable one in light of the local context and basic conditions, these elements should be discussed per measure in a CBP. Management measures can be divided into different categories:

- Mechanical management measures, such as
  - mechanical or manual removal, mowing, covering with plastic sheeting;
  - possible methods for trapping and/or killing animals such as shooting, using nets, traps, birds of prey, snares, etc.
- Chemical management measures, e.g. use of pesticides or herbicides; biocides are often also legally classified as chemical management measures;
- Biological management measures such as biocides, biological control with pathogens, fungi, predators or herbivores, heat treatment, etc.;
- Habitat management, e.g. interventions at landscape level, adapting accessibility for predators, altering the food supply, adjusting hydrological regimes, transformation management, adjusting mowing regimes, burning, grazing;
- Integrated pest management (IPM): a combination of management measures;

4.7.1 Description of the measure itself

A detailed description of the measure, with all the technical information needed for its proper implementation.

- Material
- Timing (when and how often)
- Cost

4.7.2 Non-target effects

Non-target effects are side effects that may occur during or after a particular management measure. As a rule, the choice of a particular subsidiary objective and/or measure is partly guided by an assessment of the possible effects on non-target species. As well as possible non-target effects, a best practice should also include the possible measures to minimise these adverse effects.

Examples of non-target effects include:

- side effects of mechanical management on the environment: soil compaction from the use of machinery, the impact of mowing on succession and invertebrate fauna etc.;
- by-catches or the removal of native species together with the target species – the risk of this can be minimised by using selective traps and/or setting up traps as expertly as possible so that only or mainly target species are caught;
- disturbance of vulnerable areas by entering them or carrying out actions;
- unintended victims when toxic substances are used;
- the impact of broad-spectrum pesticides on non-target organisms from the drift of these products into the environment;
- fenced-off areas becoming inaccessible to non-target species;
- meso-predator release and other undesirable and often unpredictable effects of eradication through cascade effects on the ecosystem (Courchamp et al., 1999; Simberloff, 2009; Simberloff et al., 2012);
- the establishment of organisms (predators, herbivores, pathogens, fungi, etc.) used for classical or inundative biological control, with an impact on native biota (e.g. Adriaens et al. 20013, Roy et al. 2012). This occurs mainly when non-specific predators are introduced (Sheppard et al., 2004).

4.7.3 Legislation

4.7.3.1 Permits

A description of the permits needed to carry out the measure. This description should be provided in enough detail for a manager to know which permits must be requested in specific circumstances. The legal character of the measure (e.g. control versus special hunting or ordinary hunting) and whether or not the action is part of an approved management plan for a reserve or within a management scheme) as well as the nature of the area (nature reserve, private land, public land), the means of trapping or combating to be used, etc., will be factors in determining which permits are necessary.

In complex cases, a decision tree may be a useful tool to determine which permits are needed in a concrete situation (cf. the pumpkinseed sunfish best practice of van Delft et al. (2013)). An example of a decision tree for permit applications is shown in Figure 6.

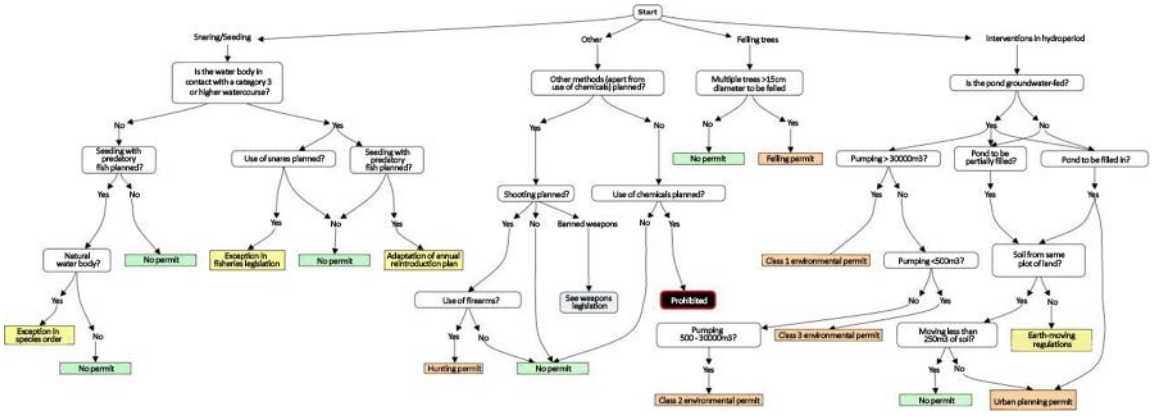

Figure 6: An example of a decision-support chart to determine which specific permit(s) is/are needed for control measures against the American bullfrog in different situations in Flanders.

Contact details of official competent authorities and organisations that issue permits or must be contacted when carrying out management measures should also be mentioned in this section of a CBP.

4.7.3.2 Other legislative requirements

These include, for example, preventive measures that must be taken before a specific form of control or hunting can be carried out under the Wildlife Order, such as taking reasonable measures to prevent damage or demonstrating that there is no other satisfactory solution for combating species.

The code of best practice regarding measures to prevent fauna damage provides the framework for mammals and birds here (Roggeman, 2014).

Any existing management regulations under the Species Order may also contain detailed guidelines for combating a species.

The current legislation on animal welfare (see 4.2) should also be included in the legislative information about each management measure in the CBP.

4.7.4 Registration and documentation of management interventions

Information should also be given for each measure about how the registration and documentation of the management intervention should be carried out. For the rapid eradication of species of concern to the EU as listed in the EU Regulation, the government has a duty to report to the European Commission. These data will also be necessary for estimating the efficiency of the measure used and the required frequency of subsequent checks.

A reference should be included to an existing standardised form for registration of the specific management activities. As a minimum, this registration will include the party carrying out the measure, date, start and end time of the management action, species concerned and specific intervention.

Reporting is also almost always one of the licensing conditions for measures subject to a permit under the Species Order.

Accurate **registration and documentation of the implementation of management measures** is indispensable to allow an evaluation of management over time and make any adjustments that are necessary.

4.7.5 Despatching and subsequent actions after control

This refers to anything relating to the further use or processing of removed plants or killed animals.
Various options should be mentioned here:

- Arrangements for leaving or storing material in situ or disposing of removed plant or animal material. In the case of plant species, information should be included about the minimum conditions for correct storage, removal or processing (e.g. preliminary drying and drainage, covering with specific materials, duration and conditions of covering, burying at a certain depth) in order to prevent re-growth or germination. If plants are dug up, attention should be paid to the removal of both the plant material and the sediment. In certain cases, it will also be necessary to check whether storage in situ is legally permitted (cf. waste legislation);
- Removal of organic material to an approved processing plant (e.g. composting of plant material at a recognised composting installation; collection of cadaver and other residual animal material by a processing operator). A best practice should indicate the conditions that material must meet for further processing to be possible (e.g. organic matter and fibre content, proportion of woody material of a certain thickness, approved containers for animal residues). Composting is often also subject to certain requirements: % admixture with standard compost, composting temperature, pre-composting period, frequency of turning, etc. Again, legal requirements or rules may apply;
- Sensible subsequent use (processing into a useful product such as compost or food; sale). Recently, there has been growing interest in controlling or eradicating populations of invasive species through harvesting. If properly applied, the encouragement of public or commercial harvesting can provide an opportunity for ecosystems and natural resources management while simultaneously promoting economic development, support and environmental awareness (Pasko et al., 2014). One example is invasive Canada geese, which are controlled in Flanders by means of catching during moulting as a nature management measure (Reyns et al. 2018). The geese are disposed of by the manager through a controlled, limited vertical market mechanism for consumption. However, improper or ill-considered use of commercial sale or harvesting may have effects which conflict with the management objective of eradication or maximum reduction of the present population. The use of invasive species for economic gain may lead to a protection reflex, the continued spread of the species or an additional increase (Nuñez et al., 2012; Simberloff et al., 2014).

To be effective as a management measure in the fight against an invasive species, harvesting must reduce the target population effectively. Knowledge of the population's biology is indispensable for this. Very often there will also be numerous legal provisions that prevent possession, transport, sale or introduction into the food chain.

4.8 Aftercare or follow-up management

Aftercare or follow-up management include the following actions:

- Actions carried out after the management measure has been performed to see if further action is needed and the implementation of such action if necessary. The best practice should describe both the method itself and the required period and necessary frequency. Some examples:
  - annual visual inspection over a period of at least five years, with additional manual removal if necessary, at sites where invasive plants have been removed;
  - the use of camera traps at bait sites for several months to check whether there are any more animals present in a particular area.
- Additional interventions at habitat level, to be carried out after the management intervention. These could involve habitat restoration, by which the ecosystem is restored to a target type or is made more resilient against future invasions (see 4.6.5), or by which, after management interventions that have created pioneer situations (e.g. removal of top layer of soil, turf-stripping), an effort is made to prevent recolonisation. Examples include planting marram grass in dune areas from which scrub has been removed, active biological management with pike after the removal of the American bullfrog (Louette, 2012), or the restoration of banks by planting with fast-growing willow species after the removal of Japanese knotweed.

4.9 Communication

Positive and transparent communication is an essential element of all possible actions involving invasive species. Communication is intended to inform and raise the awareness of all users and potential users of an area, the main aims being to reduce opportunities for further spread and (re)introduction of invasive species, increase appreciation of the need to combat introductions and the social costs of those introductions, generate understanding for the interventions and their consequences and gain support.

Some general guidelines on communicating the risks of potentially invasive species and **raising awareness** of this issue on the basis of experiences in Flanders can be found in Invexo (2013), and van Ham et al. (2013) also discuss a series of case studies in which aspects of communicating about biological invasions to different groups are covered. The experiences with various communication actions during the Invexo (2013) project showed that communication should be (species-)specific, substantiated, clear, positive and undertaken in regular doses.

Communicating the risks of potentially invasive species (risk communication) involves communicating the results of risk analysis, so that they are clearly understood and widely supported rational decisions can be taken. This forms an essential component of a (preventive) management strategy for invasive species, as well as being a general point to consider for all components (see 4.4.1). The results of risk assessments must be communicated to policy-makers and the public, whose support is needed for decisions and resulting actions. Information systems such as the Belgian Harmonia website (http://ias.biodiversity.be/) play an important role here (Vanderhoeven et al. 2015). It is important for this process to be as open and honest as possible and for the public to be able to provide input at suitable moments. Understanding, acceptance and support are essential for effective action against a nuisance species. Risk communication is a discipline in itself and lies outside the scope of this guide.

Allowance should also be made for any public reaction or sensitivities when management measures are being carried out, for example during actions in which lethal methods are used for the management of animals. Ideally, a management plan should contain a detailed communication plan, preceded by an inventory of the perceptions of relevant stakeholders and the appropriate communication channels (events, social media, written press, electronic communication, etc.) for each of these groups. Any knowledge in this area (e.g. experiences from previous campaigns) can be included in a best practice.

4.10 Additional sources and information

4.10.1 Websites

Mention websites that have been used to compile the information in a best practice, and provide links to websites where more information can be found, specifically concerning management. Some websites that are relevant to the management of invasive plant and animal species and where a lot of information and case studies can be found:

- CABI Invasive Species compendium (http://www.cabi.org/isc): very comprehensive fact sheets on invasive species around the world with information about management, invasion etc.;
- GISD Global Invasive Species Database (IUCN, 2009) (www.issg.org): fact sheets on invasive species around the world with a tab on management, numerous references to case studies from other parts of the world;
- The Eppo Global Database (https://gd.eppo.int/) with datasheets, standards and information about nuisance species on the EPPO lists;
- Q bank (http://www.q-bank.eu/): fact sheets on invasive plant species with information about speciesidentification and management options;
- The Conservation Evidence (http://www.conservationevidence.com/) website and journal of the same name, a freely accessible website with articles written by and for conservation managers about the impact of management measures, including habitat restoration and species management methods;
- United States Department of Agriculture (USDA) National Invasive Species Information Center (NISIC);
- EPPO (www.eppo.org) (EPPO, 2006; EPPO, 2009a; EPPO, 2009b): alert lists relevant to prevention, fact sheets on a number of plant species, risk analyses including options for risk management;
- The IUCN invasive alien species pages (https://www.iucn.org/theme/species/our-work/invasive-species/eu-regulation-invasive-alien-species) with documents (e.g. pathway guidance and species management reviews) supporting the implementation of the EU IAS Regulation.
- The risk assessments for the (proposed) species of Union Concern sensu the IAS Regulation that can be found through the European Commission's website (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)

4.10.2 References

Mention the sources used to compile the information in a best practice. This may seem trivial but it is often very important to the user of a best practice to be able to check whether the described method is applicable in the local context.

The accessibility of these sources should also be checked. For example, it makes little sense to indicate sources that are not publicly accessible on a general website with best practice information.

4.10.3 Workshops and symposia

Links to posters and presentations at symposia or workshops etc., which are often hard to find via direct searches in online search engines, can be useful.

4.10.4 Other contacts and links

Research has shown that managers primarily obtain information about the measures to be applied and their effectiveness through informal contacts (Matzek et al., 2013). Internal reports, online tools and posters and presentations at seminars and symposiums were also very important for information flow, with the most important information needs being knowledge about effectiveness of treatments, cost-effectiveness, alternatives to chemical treatments, non-target effects and technical questions about the specific application of herbicides.

It is therefore advisable to provide names and contact details of organisations or individuals with practical experience, subject to permission from the relevant parties.

4.10.5 Other information

Additional existing information that may be useful for managers, such as information and tips on conducting communication actions, existing awareness-raising flyers, designs for information boards used in actions, etc.

4.10.6 Disaster or contingency plan

References to any disaster or contingency plan should be included here. Such a plan indicates in general what needs to be done when an invasive species is found for the first time; it is therefore the step before a detailed management plan. It indicates the organisational structures, procedures and arrangements after an introduction of risk species has been discovered. The plan describes who has which roles and competences, and how the response is aligned with the regulations and other organisations. This plan should, as a minimum, mention the stakeholders and experts who should be contacted when more concrete actions are taken, but above all should also make clear the powers of different bodies and organisations and the procedure to be followed. Examples of such plans can be found on the website of the non-native species secretariat of Great Britain (http://www.nonnativespecies.org/) under the 'Action plans' tab. A complete best practice should of course mention such an existing emergency plan.

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