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# Monitoring schemes for species of conservation concern in Flanders (northern Belgium)

## An overview of established schemes and the design of an additional monitoring scheme

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Vegetation monitoring in the Yzer estuary (Y. Adams / Vildaphoto)

# MONITORING SCHEMES FOR SPECIES OF CONSERVATION CONCERN IN FLANDERS (NORTHERN BELGIUM)

## An overview of established schemes and the design of an additional monitoring scheme

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## Preface

Governments have a great need for good information about biodiversity to support policy, planning, evaluation, reporting and management. The regional Flemish Government is no exception to this, since biodiversity matters are their delegated competence in Belgium. Three major parts regarding monitoring information can be distinguished:

- species information;
- information on habitat types;
- information necessary for planning, monitoring, evaluating and optimizing control measures in function of the objectives set.

This report only deals with the monitoring of policy-relevant species. In order to meet this information need, the Research Institute for Nature and Forest (INBO), in collaboration with the Agency for Nature and Forests (ANB), worked out in detail which data are necessary and how they should best be collected. For this we used the guidelines for designing policy-oriented monitoring networks (Reynolds et al. 2011). This guideline distinguishes five different phases:

- Phase I: Prioritize information needs;
- Phase II: Elaborating data collection;
- Phase III: Planning data processing;
- Phase IV: Planning reporting and communication;
- Phase V: Implementation and quality assurance.

In Phase I, a detailed analysis of the demand side (information requirement) and the supply side (available information from existing monitoring schemes) was already carried out. Subsequently, the priority questions were delineated and an initial impetus was given to the methodology required in order to answer these priority questions. The Phase I results for the species have been described previously (Adriaens et al. 2011). In Phase II, the data collection for the different species was elaborated in detail. This includes the sampling method and the monitoring scheme design (number of monitoring locations and the selection procedure). Based on this, a blueprint for future data collection was drawn up for each species group (De Knijf et al. 2014). An important starting point in developing these blueprints is that data collection must be done in a cost-effective and sustainable way by involving citizen scientists. Considerable consideration was therefore given to the practical feasibility of the proposed data collection in terms of measurement effort required, use of advanced equipment and the like. The present report bundles the existing monitoring networks in Flanders and discusses how a new species monitoring network was designed to monitor the missing species relevant to policy.

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## Abstract

International and regional legislations require authorities to report regularly on the state of species of conservation concern in their region or country (e.g., the EU Birds and Habitats Directives). Monitoring schemes for species across a variety of taxonomic groups are being set up to estimate abundance trends. In Flanders (northern Belgium), until recently there were 14 established monitoring schemes covering eight taxonomic groups mainly for species of the EU Birds and Habitats Directives. After the publication of a list of species of regional conservation concern with a monitoring requirement, a quality and effectiveness check of the established monitoring schemes was executed. Some were optimised to make them more cost-effective (e.g., lower number of sampling points, lower sampling frequency). In addition, we checked for priority species that were not covered by any of the existing monitoring schemes and designed new schemes for the remaining 88 species. An important criterion for the new monitoring schemes is its applicability/feasibility by trained citizen scientists. Therefore, information needs and minimum data requirements were listed and distribution data were compiled for each species. For rare species, all known sites were to be monitored, while for more widespread species, a subset of monitoring sites was selected through a Generalised Random Tessellation Stratified sampling strategy (GRTS). Finally, for each species, a detailed monitoring protocol was generated, periodically evaluated and systematically optimised. Additionally, a web portal and mobile application were developed for entry and reporting of the monitoring data. In the future, new monitoring techniques (e.g., environmental DNA (eDNA) and other molecular identification methods (metabarcoding), automated species detection using cameras, pheromones, conservation dogs) will also be considered for integration in the monitoring schemes for elusive species. The way in which new monitoring schemes were designed for species of conservation concern in Flanders can serve as a useful example for other countries and regions.

## Samenvatting

Internationale en regionale wetgevingen vereisen dat autoriteiten regelmatig verslag uitbrengen over de staat van soorten die belangrijk zijn in het regionale of nationale natuurbehoud en -beleid (bijv. de Europese Vogel- en Habitatrichtlijn). In Vlaanderen waren er tot voor kort 14 reeds langer bestaande monitoringprogramma's die acht taxonomische groepen omvatten, voornamelijk soorten van de Europese vogel- en habitatrichtlijn. Na de publicatie van de lijst met soorten waarvoor Vlaanderen verplicht is om op regelmatige basis te rapporteren, werd een kwaliteit- en effectiviteitscontrole van de reeds lang bestaande monitoringschema's uitgevoerd. Sommige werden geoptimaliseerd om ze kosteneffectiever te maken (bv. minder bemonsteringspunten, lagere bemonsteringsfrequentie). Daarnaast gingen we na welke prioritaire soorten niet onder één van de bestaande monitoringschema’s vielen. Voor de overblijvende 88 soorten werden zo nieuwe monitoringsschema's ontworpen. Een belangrijk criterium voor de nieuwe monitoringschema's is de toepasbaarheid/haalbaarheid door getrainde burgerwetenschappers. Daarom werden informatiebehoeften en minimale gegevensvereisten geïnventariseerd en werden verspreidingsgegevens voor elke soort verzameld. Voor zeldzame soorten moeten alle bekende locaties worden gemonitord, terwijl voor meer wijdverspreide soorten een subset van monitoringlocaties werd geselecteerd via een Generalised Random Tessellation Stratified sampling strategy (GRTS). Ten slotte werd voor elke soort een gedetailleerd monitoringprotocol opgesteld, dat periodiek geëvalueerd en systematisch geoptimaliseerd wordt. Daarnaast werden een webportaal en mobiele applicaties ontwikkeld voor invoer en rapportage van de monitoringgegevens. In de toekomst wordt onderzocht in hoeverre nieuwe monitoringtechnieken (bv. omgevings-DNA (eDNA) en andere moleculaire identificatiemethoden (metabarcoding), geautomatiseerde soortdetectie met behulp van camera's, feromonen, snuffelhonden) geïntegreerd kunnen worden in de monitoringschema's voor moeilijk te monitoren soorten. De manier waarop nieuwe monitoringschema's werden ontworpen voor beleidsrelevante soorten in Vlaanderen kan als voorbeeld dienen voor andere landen en regio's.

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The Eurasian wigeon (*Mareca penelope*), one of the bird species that is monitored in the Waterbird Counts (Picture: Yves Adams – Vilda).

# 1 Introduction

Biodiversity is declining worldwide (Butchart et al. 2010; Doherty et al. 2016) and this has a potential impact on the ecosystem services it delivers (Luck et al. 2009). This has recently been shown for both vertebrates (WWF 2020), freshwater megafauna (He et al. 2019) and insects (Hallmann et al. 2017; Cardoso et al. 2020; Wagner et al. 2021). Therefore, measures to halt this decline are urgently needed (e.g., Samways et al. 2020). Policy makers are trying to stop the decline of biodiversity at the global (Convention on Biological Diversity – Green et al. 2005), continental (e.g., EU Biodiversity Strategy for 2030 – European Commission 2020, European Green Deal) and regional level (e.g., Louette et al. 2011). To assess the state of a species of conservation concern, it is important to know both its distribution (is it a rare species or does it occur more widely in the focal region?) and its trend in abundance (e.g., is it declining or increasing?) (European Environment Agency 2007). The EU Biodiversity Strategy for 2030, for example, highlights the need of species monitoring to support ambitious goals such as the proper ecological management of at least 30% of both the EU land and sea area, the implementation of a new EU Restoration Law with reporting obligations (Cortina-Segarra et al. 2021), a more biodiversity-friendly agricultural policy (with farmland birds and insects, particularly pollinators, as key indicators), the restoration of at least 25,000 km of free-flowing rivers and the greening of urban areas.

Several conventions worldwide and in Europe strongly encourage countries to report on the (regional or national) state of biodiversity, or even explicitly require it: the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (Navid 1984; Navedo & Piersma 2023), the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA – African-Eurasian Migratory Waterbirds (AEWA) 2022), the European Union's Birds Directive (Directive 79/409/EEC) and Habitats Directive (Council Directive 92/43/EEC), together called the Natura 2000 network (Sundseth & Creed 2008), the Bonn Convention on Migratory Species (CMS), the Bern Convention on the Conservation of European Wildlife and Natural Habitats, the Agreement on the Conservation of European Bats, the European Union's Eel Regulation (EC/1100/2007), the Data Collection Framework under the common fisheries policy (DCF), and the EU regulation on Invasive Alien Species (IAS, EU 1143/2014). Other conventions, such as the EU Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC, MSDF), demand monitoring of species assemblages and other indicators in order to assess the status of the

ecological integrity of the entire species community as part of an evaluation of entire (mainly aquatic) ecosystems. In addition, many national and regional authorities have decided to monitor and/or survey additional regionally threatened species (e.g., European or regional Red List species that are not considered by the legislations mentioned above). Biodiversity indicators that are used at various spatial scales to evaluate conservation policies or to prioritise conservation interventions also require monitoring data. Examples of such biodiversity indices (e.g., species that are representative for other species or for certain biotopes) are the global (Loh et al. 2005) or regional Living Planet Indices (van Strien et al. 2016) and biodiversity indicators assessing the regional state of nature (e.g., Vriens et al. 2019). Long-existing monitoring schemes to reliably estimate population trends, however, usually only cover a few well-studied species groups, such as birds (Schmeller et al. 2012; Reif 2013; Brlík et al. 2021) and butterflies (van Swaay et al. 2008; Wepprich et al. 2019).
Ideally, such monitoring schemes should (Bayraktarov et al. 2019):

- consider the research question at hand,
- have a sound ecological and statistical basis,
- be robustly designed and adaptive to the goal,
- be simple and feasible to execute in the field,
- plan for long-term execution, data quality and data accessibility,
- lead to management interventions or responses,
- be well connected with decision-making.

Species and population monitoring schemes are diverse in scale, coverage and aims. A common goal of monitoring schemes, however, is to assess changes in the abundance and/or distribution of focal species in a given region or country over time. Data for calculating species trends can be collected in three ways:

i) unstructured, i.e., via opportunistic observations; this can result in a very large number of data for popular taxonomic groups (e.g., butterflies, plants, birds), but not necessarily for under-surveyed groups (e.g., lang-legged flies; Pollet & Maes 2019), but requires complex models to correct for all kinds of biases (Bayraktarov et al. 2019; Van Eupen et al. 2021);

ii) semi-structured data, i.e., opportunistic observations (including absence) without sampling design, but with recording of search effort in time and space: mostly "complete lists" of at least species, and sometimes also numbers along a recorded track of choice. (e.g., standard protocol in eBird, recommended in waarnemingen.be);

iii) structured, i.e., via monitoring schemes (incl. detailed sampling designs and data collection protocols); this requires more professional support and results in fewer data, but ultimately a higher data reliability and simpler statistical models. Although methods exist to overcome biases in calculating species trends with opportunistic data (Isaac et al. 2014), they require benchmarking against long-term, high-quality structured data (Bayraktarov et al. 2019).

Long-term monitoring is time-consuming and expensive if executed only or mainly by professional researchers. Moreover, resources are limited and require optimisation to make monitoring both cost-effective and cost-efficient (cf. Moran-Ordonez et al. 2018). For that reason, increasingly, trained citizen scientists are involved to follow-up the status of populations of threatened species (e.g., Benshemesh et al. 2020). In addition, limited resources require optimisation to make monitoring both cost-effective and cost-efficient (cf. Moran-Ordonez et al. 2018). However, many established monitoring schemes suffer from a lack of data quality, statistical power and standardised set-up (Legg & Nagy 2006). This emphasises the need for an appropriate science-based way of monitoring species to support conservation or management policies (Lindenmayer & Likens 2010a; Lindenmayer & Likens 2010b; Reynolds et al. 2011; Toft et al. 2017; Dixon et al. 2019).

Here, we describe how we evaluated – and where needed, adapted – existing monitoring schemes and how a collaboration of governmental institutes (e.g., the Research Institute for Nature and Forest – INBO), citizen science organisations and different taxonomical study groups developed additional schemes in order to gather data on all species of conservation concern in our study region (i.e., Flanders, northern Belgium), as required by international or regional conventions or conservation priorities. They mainly focus on the assessment of long-term abundance and/or distribution trends. In a first analysis, we identified the target species that were not covered by any of the established monitoring schemes in Flanders. Subsequently, we describe how we designed and implemented new monitoring schemes for these species to maximally comply with the various conventions and/or conservation priorities. The new species monitoring schemes needed to be effective and efficient regarding statistical power, data quality and data accessibility and were designed to be executed by citizen scientists (De Knijf et al. 2014; Herremans et al. 2014). Guidelines are given on how new monitoring schemes are designed, to serve as an example for other regions or countries.

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# 2 Material and method

## 2.1 STUDY AREA

In Belgium, all conventions regarding nature conservation are delegated to the region, apart from marine conservation, which remained a federal competence. As a result, the three different administrative regions (Flanders, Wallonia and the Brussels Capital Region) need to coordinate monitoring activities in their own region to assess the status of species in response to monitoring obligations according to both international and regional conventions. The final reporting for the different international conventions, however, is done by Belgium as a member state. Here, we only report on Flanders, the northern administrative region of Belgium. Flanders covers an area of 13,522 km² and is one of the most densely populated regions in Europe (481 inhabitants/km²; www.vlaanderen.be). More than half of the territory is agricultural land and a further 26% is urbanised (Poelmans & Van Rompaey 2009). Due to habitat loss and fragmentation, anthropogenic pollution and habitat degradation (e.g., eutrophication due to nitrogen deposition), many taxonomic groups have suffered severe losses in recent times in Flanders (e.g., vascular plants – Van Landuyt et al. (2008), butterflies – Maes et al. (2022), freshwater fishes – Verreycken et al. (2014), ladybirds – Adriaens et al. (2015) and breeding birds – Devos et al. (2016)).

## 2.2 INTERNATIONAL AND REGIONAL SPECIES CONVENTIONS AND ITS CURRENT APPLICATION IN FLANDERS

First, we give an overview of the international and regional conventions which encompass species monitoring obligations or recommendations. We hereby exclude monitoring obligations where species are only used as an indicator for evaluating community structures or the ecological integrity of ecosystems (e.g., the EU Water Framework Directive, Marine Strategy Framework Directive).

A timeline of the application of the different conventions and the start of the different monitoring schemes is given in Figure 1.

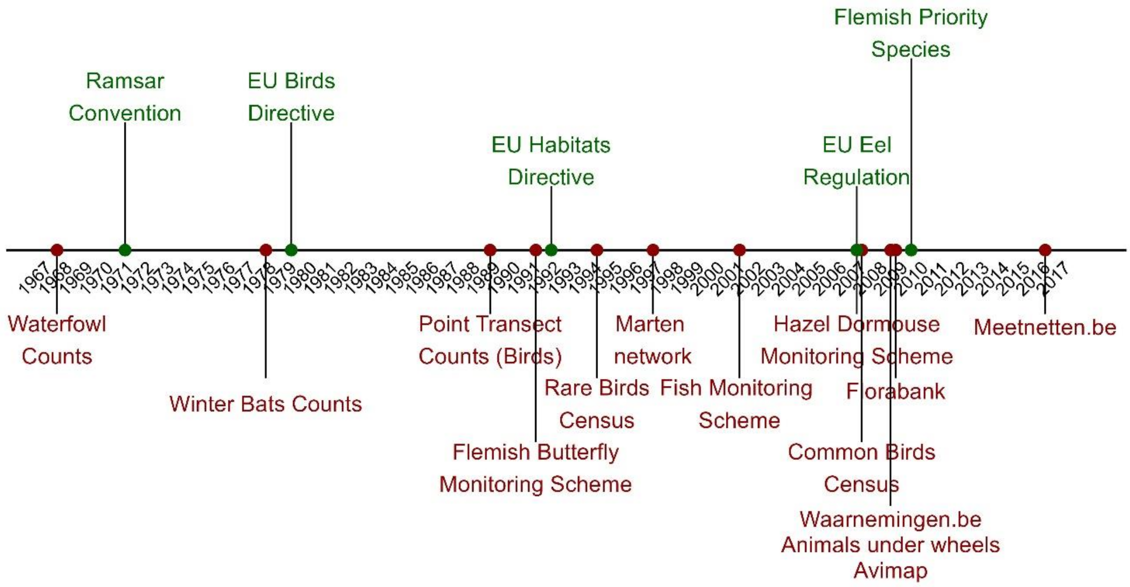


Figure 1 Timeline of the different conventions (top, green) with their entry in force and the start of the different monitoring schemes (bottom, red) in Flanders.

### 2.2.1 EU Birds Directive

The EU Birds Directive (Directive 79/409/EEC) was signed in 1979 and amended in 2009 (Directive 2009/147/EC). It demands the European Union member states to protect all naturally occurring bird species and to designate Special Protection Areas (SPA’s) for bird species listed in Annex I of the Directive. Flanders has designated 24 sites as SAC’s with a total area of 98,243 ha (7.3% of the total land area – Devos & Anselin 2017). On top of that, each member state is required to monitor and report on the state of all regularly occurring breeding birds every six years (Vermeersch et al. 2020b), with special attention to the Annex I species (e.g., Vermeersch et al. 2019). Most of the breeding bird species are monitored by the *Common Breeding Birds* (Vermeersch et al. 2018) and/or the *Rare Breeding Birds* monitoring schemes (Anselin et al. 2003; Table 1). The remaining breeding birds are surveyed within the framework of distribution atlases (e.g., Vermeersch et al. 2004; Natuurpunt Studie et al. 2019). In addition, member states should report on certain key wintering species – especially migratory waterbirds. In Flanders, mid-monthly counts from October to March cover all waterbird species present in ca. 1100 wetland sites (Devos et al. 2020). Conservation goals – including so-called Favourable Reference Values – were set for 32 breeding bird species and 26 wintering waterbird species that are listed in the Annex I or meet other criteria of the Birds

Directive (Paelinckx et al. 2009). Field criteria to evaluate if these goals are achieved were elaborated by Vermeersch et al. 2020a.

### 2.2.2 EU Habitats Directive

The EU Habitats Directive was signed in 1992 (Council Directive 92/43/EEC) and was largely based on the Bern Convention. It has several annexes referring to species. Annex II lists species for which SAC's (Special Protection Areas) must be designated. In Flanders, 38 such SAC's with a total area of 104,976 ha (7.8% of the total land area) have been established and must be managed in accordance with the ecological needs of the species and the habitat types present. For species of Annex IV, a strict protection regime must be applied across their entire natural range within the European Union, both within and outside protected areas. For Annex V species, member states must ensure that their sustainable exploitation does not jeopardise their favourable conservation status. The EU Birds Directive and Habitats Directive areas together are commonly referred to as the Natura 2000 network (Sundseth & Creed 2008). Every six years, member states need to report on the conservation status of Annex II, IV and V species for each biogeographic region present in the country under the provision of Article 17 (De Knijf et al. 2019). Criteria and thresholds for a Favourable Conservation Status of EU Habitats Directive species were recently determined for Flanders (Lommaert et al. 2020). A scheme for monitoring the biotic habitat quality of Natura 2000 habitat types was recently published as well (Westra et al. 2022).

A total of 74 taxa could be monitored in the frame of the EU Habitats Directive. However, three of them only need to be reported at the (sub)genus or family level and are not included in further analyses (lichens: *Cladonia* subgenus *Cladina* spp., mosses: Bog-moss *Sphagnum* spp., vascular plants: Clubmoss *Lycopodiaceae* spp.). Out of the 71 other EU Habitats Directive species that occur(ed) in Flanders, 38 were already monitored by six different monitoring schemes: two of them are coordinated by volunteer groups, i.e., the *Winter Bats Counts* (n = 20 species) and the *Hazel dormouse Monitoring Scheme* (n = 1) and four by professional scientists, i.e., the *Fish Monitoring Scheme* (n = 10), the monitoring scheme for plants (*Florabank*) of the EU Habitats Directive (n = 4), the *Marten Network* (n = 2) and the *Grey wolf management plan* (n = 1). Thirty-three remaining species were not covered by any established monitoring scheme until recently (Table 1; see 4.3).

### 2.2.3 EU Eel Regulation

The EU Eel Regulation was signed in 2007 (EC/1100/2007) and obliges the member states to monitor the European eel (*Anguilla anguilla*), a threatened species in both Flanders (Verreycken et al. 2014), Europe (Freyhof & Brooks 2011) and globally (Pike et al. 2020). This monitoring is achieved in Flanders through a modelling approach based on yellow (immature) eels, carried out by professional researchers in the *Fish Monitoring Scheme* (Stevens et al. 2013; Belpaire et al. 2018). Reporting is required every six years (cf. EU Birds and Habitats Directive).

### 2.2.4 Flemish Priority Species

On a regional level, the Flemish Species Decree of 2009 (Flemish Government 2009) compiled a list of Flemish Priority Species (De Knijf et al. 2013). Next to all species of the EU Birds and Habitats Directives, a selection was made of species that are:

- i) on the European and/or Flemish Red List,
- ii) decreasing in Western Europe and/or
- iii) typical for Annex I habitats of the EU Habitats Directive.

These species must be monitored for Flemish nature conservation policies (Westra et al. 2016). A total of 57 species are considered as Flemish Priority Species including 49 that were not monitored by any established monitoring scheme until recently (Table 1).

### 2.2.5 Other international conventions

Three other international conventions regarding species (and their habitats) are the Ramsar Convention, the Bern Convention and the Bonn Convention. The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat, hereafter called the Ramsar Convention, was signed in 1971 in Iran. It is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources with special emphasis on migratory waterbirds (Navid 1984). Each signing member of the convention has to designate suitable wetlands within its territory that are subsequently included in a List of Wetlands of International Importance, so-called Ramsar sites. One of the most known criteria for this designation is the regular occurrence of at least 1% of the biogeographical population of one or more waterbird species, or the presence of more than 20,000 waterbirds of one or more species at the concerned site. Belgium designated nine Ramsar sites with four situated in the Flemish administrative region (Kuijken et al. 1996).

The Bern Convention came into effect in 1979 and was the basis for the species lists in Annexes II and/or IV of the EU Habitats Directive (European Commission 1992).

The Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals or CMS) entered into force in 1983 and aims to achieve the conservation of terrestrial, marine and avian migratory species throughout their range. In Flanders, all species of the Bern and/or Bonn Convention are covered by other conventions such as the EU Birds and Habitats Directives (apart from some rare exceptions, e.g., the fishes Sunbleak (*Leicaspius delineates*) and Common goby (*Pomatoschistus microps*)).

The most recent European species legislation is the EU regulation on the prevention and management of the introduction and spread of invasive alien species (IAS; EU 1143/2014). This Regulation stipulates that Member States should set up surveillance systems for IAS of Union Concern. These systems should be designed to monitor the effectiveness of eradication, population control or containment measures and should be able to assess the impact of management on non-target species. Since the objectives and methods (e.g., early warning, surveillance) are quite different from those that are applied to protected species, this legislation will not further be treated here, but we refer to other relevant works whenever possible (Adriaens et al. 2019; Adriaens et al. 2020a; D'hondt et al. 2022). We do, however, mention when the monitoring schemes also yield useful data on IAS of European Union Concern.

In Table 1, we give an overview of all species with monitoring obligations in Flanders.

Table 1 Species with monitoring obligations or recommendations per legislation and the associated monitoring scheme (excl. EU IAS Regulation). Scientific, and vernacular species name in English and Dutch (between brackets) is given.

| **EU Birds Directive** | | **Monitoring scheme** |
|---|---|---|
| All species | | Rare & Common Birds Census, Waterbird Counts |
| **EU Habitats Directive (74)** | | |
| *Amphibians (10)* | | |
| *Alytes obstetricans* | Midwife toad (Vroedmeesterpad) | - |
| *Epidalea calamita* | Natterjack toad (Rugstreeppad) | - |
| *Hyla arborea* | European tree frog (Boomkikker) | - |
| *Pelobates fuscus* | Common spadefoot toad (Knoflookpad) | - |
| *Pelophylax klepton esculentus* | Edible frog (Bastaardkikker) | - |
| *Pelophylax lessonae* | Pool frog (Poelkikker) | - |
| *Pelophylax ridibundus* | Marsh frog (Meerkikker) | - |
| *Rana arvalis* | Moor frog (Heikikker) | - |
| *Rana temporaria* | Common frog (Bruine kikker) | - |
| *Triturus cristatus* | Great Crested newt (Kamsalamander) | - |
| *Bats (20)* | | |
| *Barbastella barbastellus* | Western barbastelle (Mopsvleermuis) | Winter Bats Counts |
| *Eptesicus serotinus* | Serotine bat (Laatvlieger) | Winter Bats Counts |
| *Myotis bechsteinii* | Bechstein’s bat (Bechsteins vleermuis) | Winter Bats Counts |
| *Myotis brandtii* | Brandt’s bat (Brandts vleermuis) | Winter Bats Counts |
| *Myotis dasycneme* | Pond bat (Meervleermuis) | Winter Bats Counts |
| *Myotis daubentonii* | Daubenton's bat (Watervleermuis) | Winter Bats Counts |
| *Myotis emarginatus* | Geoffroy’s bat (Ingekorven vleermuis) | Winter Bats Counts |
| *Myotis myotis* | Greater mouse-eared bat (Vale vleermuis) | Winter Bats Counts |
| *Myotis mystacinus* | Whiskered bat (Baardvleermuis) | Winter Bats Counts |
| *Myotis nattereri* | Natterer’s bat (Franjestaart) | Winter Bats Counts |
| *Nyctalus leisleri* | Lesser noctule (Bosvleermuis) | Winter Bats Counts |
| *Nyctalus noctula* | Noctule (Rosse vleermuis) | Winter Bats Counts |
| *Pipistrellus nathusii* | Nathusius’s pipistrelle (Ruige dwergvleermuis) | Winter Bats Counts |
| *Pipistrellus pipistrellus* | Common pipistrelle (Gewone dwergvleermuis) | Winter Bats Counts |
| *Pipistrellus pygmaeus* | Soprano pipistrelle (Kleine dwergvleermuis) | Winter Bats Counts |
| *Plecotus auritus* | Brown long-eared bat (Gewone grootoorvleermuis) | Winter Bats Counts |
| *Plecotus austriacus* | Grey long-eared bat (Grijze grootoorvleermuis) | Winter Bats Counts |
| *Rhinolophus ferrumequinum* | Greater horseshoe bat (Grote hoefijzerneus) | Winter Bats Counts |
| *Rhinolophus hipposideros*† | Lesser horseshoe bat (Kleine hoefijzerneus) | Winter Bats Counts |
| *Vespertilio murinus* | Parti-coloured bat (Tweekleurige vleermuis) | Winter Bats Counts |
| *Beetles (3)* | | |
| *Cucujus cinnaberinus* | Red flat bark beetle (Vermiljoenkever) | - |
| *Lucanus cervus* | Stag beetle (Vliegend hert) | - |
| *Osmoderma eremita* | Hermit beetle (Juchtleerkever) | - |

| | | |
|---|---|---|
| *Butterflies (1)* | | |
| *Euphydryas aurinia* | Marsh fritillary (Moerasparelmoervlinder) | - |
| *Dragonflies (4)* | | |
| *Stylurus flavipes* | River clubtail (Rivierrombout) | - |
| *Leucorrhinia caudalis* | Lilypad whiteface (Sierlijke witsnuitlibel) | - |
| *Leucorrhinia pectoralis* | Large whiteface (Gevlekte witsnuitlibel) | - |
| *Ophiogomphus cecilia* | Green snaketail (Gaffellibel) | - |
| *Fishes (10)* | | |
| *Alosa fallax* | Twaite shed (Fint) | Fish Monitoring Scheme |
| *Barbus barbus* | Common barbel (Barbeel) | Fish Monitoring Scheme |
| *Cobitis taenia* | Spined loach (Kleine modderkruiper) | Fish Monitoring Scheme |
| *Cottus perifretum* | Bullhead (Rivierdonderpad) | Fish Monitoring Scheme |
| *Cottus rhenanus* | Rhine sculpin (Beekdonderpad) | Fish Monitoring Scheme |
| *Lampetra fluviatilis* | European river lamprey (Rivierprik) | Fish Monitoring Scheme |
| *Lampetra planeri* | Brook lamprey (Beekprik) | Fish Monitoring Scheme |
| *Misgurnus fossilis* | European weatherfish (Grote modderkruiper) | Fish Monitoring Scheme |
| *Rhodeus amarus* | European bitterling (Bittervoorn) | Fish Monitoring Scheme |
| *Salmo salar* | Atlantic salmon (Atlantische zalm) | Fish Monitoring Scheme |
| *Lichens (1)* | | |
| *Cladonia* subgenus *Cladina* spp. | Cladonia | Waarnemingen.be |
| *Non-flying mammals (9)* | | |
| *Canis lupus* | Grey wolf (Grijze wolf) | Marten Network |
| *Castor fiber* | Eurasian beaver (Europese bever) | - |
| *Cricetus cricetus* | European hamster (Europese hamster) | - |
| *Felis silvestris* | European wildcat (Europese wilde kat) | Marten Network |
| *Lutra lutra* | Eurasian otter (Europese otter) | Marten Network |
| *Lynx lynx* | Eurasian lynx (Euraziatische lynx) | Marten Network |
| *Martes martes* | Pine marten (Boommarter) | Marten Network |
| *Muscardinus avellanarius* | Hazel dormouse (Hazelmuis) | Hazel dormouse Monitoring Scheme |
| *Mustela putorius* | Western polecat (Bunzing) | Marten Network |
| *Molluscs (5)* | | |
| *Anisus vorticulus* | Ramshorn snail (Platte schijfhoren) | - |
| *Helix pomatia* | Burgundy snail (Wijngaardslak) | - |
| *Unio crassus* | Thick shelled river mussel (Bataafse stroommossel) | - |
| *Vertigo angustior* | Narrow-mouthed whorl snail (Nauwe korfslak) | - |
| *Vertigo moulinsiana* | Desmoulins whorl snail (Zeggekorfslak) | - |

| | | |
|---|---|---|
| *Mosses (2)* | | |
| *Hamatocaulis vernicosus* | Varnished hook-moss (Geel schorpioenmos) | Florabank |
| *Leucobryum glaucum* | Large white-moss (Kussentjesmos) | Waarnemingen.be |
| *Sphagnum* spp. | Bog-moss | Waarnemingen.be |
| *Moths (2)* | | |
| *Euplagia quadripunctaria* | Jersey tiger (Spaanse vlag) | Nachtvlindermeetnet |
| *Proserpinus proserpina* | Willowherb hawkmoth (Teunisbloempijlstaart) | Nachtvlindermeetnet |
| *Reptiles (2)* | | |
| *Coronella austriaca* | Smooth snake (Gladde slang) | - |
| *Podarcis muralis* | Common wall lizard (Muurhagedis) | - |
| *Vascular plants (3)* | | |
| *Apium repens* | Creeping marshwort (Kruipend moerasscherm) | Florabank |
| *Liparis loeselii* | Fen orchid (Groenknolorchis) | Florabank |
| *Luronium natans* | Floating water-plantain (Drijvende waterweegbree) | Florabank |
| *Lycopodiaceae* spp. | Clubmoss | Waarnemingen.be |
| **EU Eel Regulation (1)** | | |
| *Anguilla anguilla* | European eel (Paling) | Fish Monitoring Scheme |
| **Flemish Priority Species (58)** | | |
| *Amphibians (1)* | | |
| *Salamandra salamandra* | Fire salamander (Vuursalamander) | - |
| *Beetles (1)* | | |
| *Elater ferrugineus* | Rusty click beetle (Roestbruine kniptor) | - |
| *Breeding birds (6)* | | |
| *Anthus trivialis* | Tree pipit (Boompieper) | Common Birds Census |
| *Athene noctua* | Little owl (Steenuil) | Rare Birds Census |
| *Emberiza calandra* | Corn bunting (Grauwe gors) | Rare Birds Census |
| *Limosa limosa* | Black-tailed godwit (Grutto) | Common Birds Census |
| *Oriolus oriolus* | Eurasian golden oriole (Wielewaal) | Common Birds Census |
| *Podiceps nigricollis* | Black-necked grebe (Geoorde fuut) | Rare Birds Census |

| *Butterflies (12)* | | |
|---|---|---|
| *Apatura iris* | Purple emperor (Grote weerschijnvlinder) | - |
| *Cyaniris semiargus* | Mazarine blue (Klaverblauwtje) | - |
| *Erynnis tages* | Dingy skipper (Bruin dikkopje) | - |
| *Euphydryas aurinia* | Marsh fritilllary (Moerasparelmoervlinder) | - |
| *Hesperia comma* | Silver-spotted skipper (Kommavlinder) | - |
| *Hipparchia semele* | Grayling butterfly (Heivlinder) | - |
| *Lasiommata megera* | Wall brown (Argusvlinder) | - |
| *Melitaea cinxia* | Glanville fritillary (Veldparelmoervlinder) | - |
| *Phengaris alcon* | Alcon blue (Gentiaanblauwtje) | - |
| *Pyrgus malvae* | Grizzled skipper (Aardbeivlinder) | - |
| *Pyronia tithonus* | Gatekeeper (Oranje zandoogje) | Flemish Butterfly Monitoring Scheme |
| *Satyrium ilicis* | Ilex hairstreak (Bruine eikenpage) | - |

| *Dragonflies (8)* | | |
|---|---|---|
| *Aeshna isoceles* | Green-eyed hawker (Vroege glazenmaker) | - |
| *Calopteryx virgo* | Beautiful demoiselle (Bosbeekjuffer) | - |
| *Coenagrion hastulatum* | Northern damselfly (Speerwaterjuffer) | - |
| *Coenagrion lunulatum* | Irish damselfly (Maanwaterjuffer) | - |
| *Coenagrion pulchellum* | Variable damselfly (Variabele waterjuffer) | - |
| *Gomphus vulgatissimus* | Common clubtail (Beekrombout) | - |
| *Somatochlora arctica* | Northern emerald (Hoogveenglanslibel) | - |
| *Sympetrum depressiusculum* | Spotted darter (Kempense heidelibel) | - |

| *Grasshoppers (2)* | | |
|---|---|---|
| *Ephippiger diurnus* | European bushcricket (Zadelsprinkhaan) | - |
| *Stenobothrus stigmaticus* | Lesser mottled grasshopper (Schavertje) | - |

| *Mammals (2)* | | |
|---|---|---|
| *Crocidura leucodon* | Bicolored shrew (Veldspitsmuis) | - |
| *Meles meles* | Eurasian badger (Das) | Marten Network |

| *Spiders (2)* | | |
|---|---|---|
| *Dolomedes fimbriatus* | Raft spider (Gerande oeverspin) | - |
| *Eresus sandaliatus* | Ladybird spider (Lentevuurspin) | - |

*Vascular plants (24)*

| | | |
|---|---|---|
| *Bupleurum tenuissimum* | Slender hares-ear (Fijn goudscherm) | - |
| *Carex diandra* | Lesser tussock-sedge (Ronde zegge) | - |
| *Deschampsia setacea* | Bog hair-grass (Moerassmele) | - |
| *Diphasiastrum tristachyum* | Blue ground-cedar (Kleine wolfsklauw) | - |
| *Eriophorum gracile* | Slender cottongrass (Slank wollegras) | - |
| *Gentianella uliginosa* | Dune gentian (Duingentiaan) | - |
| *Halimione pedunculata* | Pedunculate sea-purslane (Gesteelde zoutmelde) | - |
| *Hammarbya paludosa* | Bog orchid (Veenmosorchis) | - |
| *Herminium monorchis* | Musk orchid (Honingorchis) | - |
| *Juncus capitatus* | Dwarf rush (Koprus) | - |
| *Mentha pulegium* | Pennyroyal (Polei) | - |
| *Orchis morio* | Green-winged orchid (Harlekijn) | - |
| *Orchis purpurea* | Lady orchid (Purperorchis) | - |
| *Orobanche rapum-genistae* | Greater broomrape (Grote bremraap) | - |
| *Platanthera bifolia* | Lesser butterfly orchid (Welriekende nachtorchis) | - |
| *Potamogeton acutifolius* | Sharp-leaved pondweed (Spits fonteinkruid) | - |
| *Potamogeton coloratus* | Fen pondweed (Weegbreefonteinkruid) | - |
| *Potamogeton compressus* | Grasswrack pondweed (Plat fonteinkruid) | - |
| *Ranunculus ololeucos* | White flowered buttercup (Witte waterranonkel) | - |
| *Schoenoplectus pungens* | Sharp club-rush (Stekende bies) | - |
| *Schoenoplectus triqueter* | Triangular club-rush (Driekantige bies) | - |
| *Scorzonera humilis* | Vipers grass (Kleine schorseneer) | - |
| *Stratiotes aloides* | Water soldier (Krabbenscheer) | - |
| *Wahlenbergia hederacea* | Ivy-leaved bellflower (Klimopklokje) | - |

### 2.2.6 Opportunistic observations (waarnemingen.be)

Apart from the extant monitoring schemes mentioned in the previous sections, a multi-thematic data portal started is in Flanders in 2008 i.e., Waarnemingen.be (Herremans et al. 2018) as a local portal of the international system observation.org. Mostly opportunistic (presence only) and semi-structured observations (full lists including search effort data) by citizen scientists are collected. It is hosted and promoted by Natuurpunt Studie, the largest nature conservation NGO in Flanders. It stores observations of all species, regardless of monitoring obligations. It currently holds ca. 43 million records of 23,142 species and 94,000 full lists from point or transect counts, which makes Flanders an area with one of the highest densities of wildlife records in the world. Grid cell data can be consulted online via Waarnemingen.be and raw data with point locations are available on demand. Additionally, most data are published on GBIF at 1 x 1 km² or 5 x 5 km² resolution (e.g., Adriaens et al. 2020b; Maes et al. 2016).

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The Lilypad whiteface (Leucorrhinia caudalis), one of the dragonflies that is monitored in Meetnetten.be (Picture: Jeroen Mentens – Vilda).

# 3 Established monitoring schemes in Flanders

In Flanders, 14 established monitoring schemes are in place. We give a short description of each of them and discuss the applied protocol, published data sets and publications that are (partly) based on the monitoring data.

## 3.1 AMPHIBIANS

### 3.1.1 Spring migration counts

*Dominique Verbelen (Natuurpunt Studie)*

The spring migration of amphibians is monitored at approximately 275 locations in Flanders, spread (but unstratified) across the five provinces. The earliest data date back to 1981 when the numbers of migrating amphibians were only counted at one single site. Since then, the number of monitored locations for this spring migration has gradually increased each year, reaching its peak in 2021 with data gathered from 322 sites. At the beginning of the spring migration, all local coordinators are informed that, from that point on, all sites should be checked daily from dusk onwards.

There are two main methods used to monitor the outbound spring migration of amphibians. At certain sites, roads are patrolled, and any amphibians crossing the road are identified, and if possible, their sex and age are determined. They are then safely transported to the other side of the road. At other sites, monitoring is conducted in a more standardized manner. Low fences, either permanent or temporary, are constructed along the sides of roads that intersect with the migratory routes of amphibians heading towards their breeding ponds. Along these fences, buckets are dug into the ground to capture any animals attempting to cross the road. The buckets are ideally placed at intervals of 20 meters or less and are checked at least once a day by volunteers, preferably in the early morning. During this check-up, the volunteers carefully remove the amphibians from the bucket traps and transfer them across the road, allowing them to continue their journey towards the breeding ponds. This monitoring method is more standardized than the previous one, as it captures all amphibians attempting to cross the road.

The start and end of the outbound spring migration largely depend on weather conditions but generally occur between February 15th and March 31st. Although data is collected for all migrating species, the dataset primarily consists of information on the Common Toad (*Bufo bufo*) and the Common Frog (*Rana temporaria*), which are the most abundant species observed during the spring migration. At present, the dataset contains over 287,295 records of 4,140,346 toads, frogs, and newts, including data on European Priority Species such as the Natterjack Toad, Moor Frog, and Crested Newt. In terms of more common species, this monitoring scheme is the only long-running program available. A detailed overview of the data can be found here.

#### 3.1.1.1 Protocol

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#### 3.1.1.2 Datasets

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#### 3.1.1.3 Publications

Verbelen et al. (2008); Verbelen & Herremans (2010).

#### 3.1.1.4 References


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## 3.2 BIRDS

### 3.2.1 Wintering Waterbird Counts

*Koen Devos (INBO)*

All wintering waterbirds in Flanders are covered by the *Wintering Waterbird Counts* (Watervogeltellingen) monitoring scheme that started in 1967 (Van der Vloet 1967). The protocol consists of mid-monthly counts of all wintering waterbirds during the period October -March in a set of designated areas. Since the beginning of the Waterbird Counts, 170 species have been observed (Devos et al. 2020b). In Flanders, conservation goals were set for 26 wintering waterbirds species: 22 species regularly or occasionally reach the 1% wintering population level and another four species for which Flanders is considered to be an important wintering region. The scheme is coordinated by INBO and the majority of the data is collected by citizen scientists. Data are stored in a web portal (watervogels.inbo.be) and are periodically published on GBIF. The data are used for international reporting such as the population status for AEWA, for the six-yearly EU Birds Directive reporting and for the Bern Convention international action plan on the protection of White-headed duck (*Oxyura leucocephala*) and the eradication of the Ruddy duck (*Oxyura jamaicensis*; Robertson et al. 2015). The Flemish Waterbird Counts also include the monitoring of invasive alien species such as Egyptian goose (*Alopochen aegyptiaca*) and are therefore also used for reporting under the EU IAS Regulation.

#### 3.2.1.1 Protocol

Hornman et al. (2012).

#### 3.2.1.2 Datasets

Devos et al. (2020b); Devos et al. (2022a).

#### 3.2.1.3 Publications

Devos et al. (1997); Devos et al. (1998); Devos et al. (1999); Ysebaert et al. (2000); Devos et al. (2001); Anselin & Devos (2005); Devos et al. (2005); Devos et al. (2007); Devos & Kuijken (2010); Devos (2011); Devos & Kuijken (2012); Devos (2013); Devos & Onkelinx (2013); Devos (2014); Devos (2015); Devos & T'jollyn (2016); Devos & T'jollyn (2017); Devos (2018); Laubek et al. (2019); Beekman et al. (2019); Devos et al. (2019); Pavón-Jordán et al. (2019); Devos et al. (2020a); Devos et al. (2020b); Devos et al. (2022b); Devos & Kuijken (2020); Pavón-Jordán et al. (2020); Devos et al. (2021); Gaget et al. (2021); Gaget et al. (2022).

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### 3.2.2 Point-Transect-counts for wintering birds

*Pieter Van Dorsselaer* (Natuurpunt Studie)

The Point-Transect-Counts (PTT) for wintering birds started in Flanders in 1989 (Herremans 2010). Between early December and late January, but preferably as close to late December as possible, all birds are counted during five minutes at 20 fixed points along a transect. Transects are chosen by the participants to this monitoring action. For resident species it provides numerical data and a population trend index of the local population. For migrant and overwintering species the data are more difficult to interpret because winter populations are composed of birds from different origins, each with their own dynamics. However, in the context of rapid changes in migratory behaviour due to climate change effects, which affects the composition of wintering bird communities (Lehikoinen et al. 2021), monitoring wintering populations is also relevant. The scheme is coordinated by Natuurpunt Studie and all data are collected by citizen scientists. Data are managed in a private database by Natuurpunt Studie and are available on demand.

#### 3.2.2.1 Protocol

van Manen & de Jong (2016).

#### 3.2.2.2 Datasets

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#### 3.2.2.3 Publications

Herremans (2010); Lehikoinen et al. (2021).

#### 3.2.2.4 References

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### 3.2.3 Rare Breeding Birds Project

*Glenn Vermeersch (INBO), Gerald Driessens & Simon Feys (Natuurpunt Studie)*

The *Rare Breeding Birds Project* (Bijzondere Broedvogels Vlaanderen – BBV) started in 1994 and covers a selection of rare, colonial and/or non-native breeding birds in Flanders that have less than 150 breeding pairs in Flanders (Anselin et al. 1999). The complete list of 69 species that are monitored (including EU Birds Directive and 3 Flemish Priority Species) is given in Vermeersch et al. (2006). The protocol is an unstructured 'total count' approach and consists of counting the number of breeding pairs or territories of each species in all known and/or potential breeding sites, to achieve a coverage as complete as possible in Flanders. The scheme is currently coordinated by INBO, in co-operation with Natuurpunt Studie. Most data are collected by experienced citizen scientists. Data are stored in Waarnemingen.be and are available on demand. The recent development of a module for mapping rare breeding birds makes it possible to compile all regional records from waarnemingen.be and AviMap (see further) and subsequently estimate the number of breeding pairs per species.

#### 3.2.3.1 Protocol

Anselin et al. (2003).

#### 3.2.3.2 Datasets

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#### 3.2.3.3 Publications

Devos & Anselin (1996); Anselin et al. (1998); Anselin et al. (1999); Anselin et al. (2014); Devos et al. (2016a); Devos et al. (2016b); Vermeersch et al. (2020).

#### 3.2.3.4 References

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### 3.2.4 Common Breeding Birds Project

*Glenn Vermeersch, Koen Devos & Thierry Onkelinx (INBO) & Simon Feys (Natuurpunt Studie)*

The *Common Breeding Birds Project* (Algemene Broedvogelmonitoring Vlaanderen – ABV) started in 2007 and covers 101 species. The scheme is currently coordinated by INBO, while Natuurpunt Studie is responsible for data collection by citizen scientists. Data are stored in a web portal (Meetnetten.be) and are regularly published on GBIF. From the UTM 1 x 1 km² grid of Flanders, 1200 grid cells were randomly stratified over six habitat types (farmland, woodland, urban, suburban, heathland and marshland). Within each grid cell, six counting points were selected following a fix-grid pattern. Each of these points has to be counted three times per year in predefined periods: 01/03-15/04, 16/04-31/05 and 01/06-15/07. All six points in a square have to be counted in the morning on the same day and subsequent counts of the same points in different periods should be least two weeks apart.

#### 3.2.4.1 Protocol

Vermeersch et al. (2018).

#### 3.2.4.2 Datasets

Vermeersch et al. (2021); Piesschaert et al. (2022).

### 3.2.4.3 Publications

Vermeersch et al. (2007a); Vermeersch et al. (2007b); Vermeersch & Anselin (2009); Vermeersch & Onkelinx (2012); Vermeersch et al. (2014); Devos et al. (2016a); Devos et al. (2016b); Vermeersch et al. (2019); Onkelinx et al. (2020); Vermeersch et al. (2020); Onkelinx et al. (2021); Onkelinx et al. (2023).

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### 3.2.5 AviMap

*Gerald Driessens (Natuurpunt Studie) & Glenn Vermeersch (INBO)*

The Avimap tool (available via avimap.be) was launched in order to be able to follow up local, often annual, territory maps of birds for breeding bird reports. Natuurpunt 'adopted' the AviMap project from the Dutch SOVON (Kenniscentrum voor verspreiding en trends van in het wild levende vogels in Nederland, Nijmegen, Netherlands) in 2008 and expanded it further on the volunteer network and the monitoring networks in Flanders. Territorial mapping has clearly become more popular than before because initially the delineation of territories had to be done manually (draw on maps, calculate territories yourself ...). Due to the current work on a new breeding bird atlas, in which the Avimap application is widely used, it is expected that the number of users will increase considerably in the coming years. In a number of areas, territorial surveys have now been carried out for more than 10 consecutive years, covering almost all species. Many voluntary employees have a 'home patch' where they closely follow ornithological developments every year. Some are also conservators or managers of a local nature reserve. Increasingly, data is also being entered by professional counters in the context of long-term projects such as the monitoring of the Waasland Port (Spanoghe et al. 2015), Sigma areas (Leloup et al. 2007) and polder complexes in our coastal polders (Verstraete et al. 2017). At the beginning of 2020, the counter stood at 899 different 'plots' or areas with data on territory mapping. In 2022, 171 plots (total area: 19,324 ha) were surveyed through 1273 area visits according to the applicable standards for breeding bird mapping by a total of 115 volunteers. This resulted in a total of 24,462 territories of 149 different bird species.

#### 3.2.5.1 Protocol

Vergeer et al. (2017).

#### 3.2.5.2 Datasets

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### 3.2.5.3 Publications

Driessens (2023).

### 3.2.5.4 References

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Black-tailed godwit (*Limosa limosa*), one of the bird species that is monitored in the Common Birds Census monitoring scheme (Picture: Yves Adams– Vilda).

## 3.3 BUTTERFLIES & MOTHS

### 3.3.1 Flemish Butterfly Monitoring Scheme

*Dirk Maes (INBO)*

The *Flemish Butterfly Monitoring Scheme* (Algemene vlindermonitoring) started in 1991 (van Swaay et al. 1997). The scheme is coordinated by INBO and all data are collected by citizen scientists. The protocol consists of counting all butterfly species along fixed transects in an imaginary box (2.5m to each side of the observer, 5m high and 5m ahead), weekly from April to September. In Flanders, a total of 105 butterfly transects has been counted, but recently only ca. 10 transects are still active (Maes et al. 2020b). Data are stored in a webportal (Meetnetten.be) and also in the database of the European Butterfly Monitoring Scheme (eBMS; https://butterfly-monitoring.net/ebms). The data for Flanders are published yearly on GBIF and data from the eBMS are available on demand. This scheme covers the more common butterfly species in Flanders, including the Gatekeeper *Pyronia tithonus*, a Flemish Priority Species.

#### 3.3.1.1 Protocol

Maes et al. (2019); Sevilleja et al. (2019).

#### 3.3.1.2 Datasets

Maes et al. (2016); Piesschaert et al. (2022a); Piesschaert et al. (2022b); Piesschaert et al. (2022c).

#### 3.3.1.3 Publications

van Swaay et al. (1997); Maes et al. (2015); Maes et al. (2019); van Swaay et al. (2010); van Swaay et al. (2012); van Swaay et al. (2015); van Swaay et al. (2016); van Swaay et al. (2019); Maes et al. (2020a); Maes et al. (2020b); Maes et al. (2021a); Maes et al. (2021b).

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### 3.3.2 Moth Monitoring Scheme

*Wim Veraghtert (Natuurpunt Studie)*

The *Moth Monitoring Scheme* (Nachtvlindermeetnet) started in 2009 under the coordination of Natuurpunt Studie (Veraghtert et al. 2019). The aim is to monitor trends in the abundance of common (macro-)moths via standardised counts. A network of citizen scientists catches moths in their gardens using a skinner trap with a mercury vapor lamp of 125W or a similar mixed light lamp of 160W. The protocol (Veraghtert et al. 2023) prescribes sampling throughout the night and counting the numbers of moths in (and around) the trap at sunrise (and releasing them afterwards). In the period 2009-2022, 268 locations are monitored resulting in trend calculations for 247 species. Data are stored in Waarnemingen.be.

#### 3.3.2.1 Protocol

Veraghtert et al. (2019).

#### 3.3.2.2 Datasets

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#### 3.3.2.3 Publications

Veraghtert et al. (2012); Veraghtert et al. (2019); Veraghtert (2020); Veraghtert et al. (2023).

#### 3.3.2.4 References

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# 3.4 FRESHWATER FISH

## 3.4.1 Fish Monitoring Scheme

*Gerlinde Van Thuyne, Claude Belpaire & Jan Breine (INBO)*

The *Fish Monitoring scheme* (Vis Informatie Systeem – VIS) using a standardised methodology started in 1992 in the freshwater habitat, in 1995 in the brackish Zeeschelde-estuary and in 2008 in the brackish IJzer-estuary covering all fish species in Flanders (Breine et al. 2007; Speybroeck et al. 2008). The scheme is coordinated by INBO and data are collected by government employed and citizen scientists. Data are stored in the publicly available Fish Information System (vis.inbo.be) and are regularly published on GBIF. Since its start, the Fish Monitoring scheme already detected 69 species in rivers, canals and lakes and 87 species in the estuaries in Flanders. It covers 15 species with monitoring obligations: ten EU Habitats Directive species, four invasive alien species and one European Eel Regulation species.

### 3.4.1.1 Protocol

Geeraerts & Quataert (2012).

### 3.4.1.2 Datasets

Breine et al. (2021a); Breine et al. (2021c); Van Thuyne et al. (2021a); Van Thuyne et al. (2021b); Verreycken & Brosens (2021).

### 3.4.1.3 Publications

Verreycken et al. (1991); Denayer & Belpaire (1994); Van Thuyne et al. (1995); Vanden Auweele et al. (1997); Smolders et al. (1998); Volckaert et al. (1998); Belpaire et al. (2000); Goemans et al. (2003); Roose et al. (2003); Breine et al. (2004); Morris et al. (2004); Versonnen et al. (2004); Maes et al. (2005); Goethals et al. (2006); Verreycken et al. (2007); Belpaire & Goemans (2007a); Belpaire & Goemans (2007b); Bervoets et al. (2007); Bilau et al. (2007); Breine et al. (2007); Belpaire et al. (2008); Maes et al. (2008); Roosens et al. (2008); Belpaire et al. (2009); Schneiders et al. (2009); Roosens et al. (2010); Verreycken et al. (2010); Belpaire et al. (2011a); Belpaire et al. (2011b); Geeraerts et al. (2011); Verreycken et al. (2011a); Verreycken et al. (2011b); Pujolar et al. (2012); Verreycken et al. (2012); Maes et al. (2013); Pujolar et al. (2013); Stevens et al. (2013); Malarvannan et al. (2014); Van Ael et al. (2014); Verreycken et al. (2014); Belpaire et al. (2015a); Belpaire et al. (2015b); Brosens et al. (2015); Malarvannan et al. (2015); Bonnineau et al. (2016); Schauvliege (2017); Belpaire et al. (2018); De Meyer et al. (2018); Teunen et al. (2018); Slootmaekers et al. (2019); Van Thuyne et al. (2019); Bourillon et al. (2020); Breine et al. (2021b); Teunen et al. (2021a); Teunen et al. (2021b); Bourillon et al. (2022); Teunen et al. (2022a); Teunen et al. (2022b).

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European eel (*Anguilla anguilla*), one of the fish that is monitored in the Fish Monitoring network (Picture: Yves Adams– Vilda).

## 3.5 MAMMALS

### 3.5.1 Winter Bats Counts

*Sanne Ruyts & Vleermuizenwerkgroep (Natuurpunt Studie)*

The *Winter Bats Counts* (Wintertellingen Vleermuizen) are used to monitor hibernating bats. The first counts date from 1971 with reliable data available since 1978 (Lefevre & Boers 2009). The scheme is coordinated by the Vleermuizenwerkgroep of Natuurpunt Studie and all data are collected by citizen scientists. The protocol consists of counting hibernating bats in as many hibernation objects as possible during the winter months (December – February). The scheme covers all bat species that overwinter in caves and man-made structures (e.g., icehouses, bomb shelters). Data have largely been stored in the private database of the Bats Working Group of Natuurpunt Studie and were available on demand. Recently, both newly collected as well as past monitoring data are being transferred to the database that supports Meetnetten.be, which then will serve as authentic data source.

#### 3.5.1.1 Protocol

Willems et al. (2009).

#### 3.5.1.2 Datasets

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#### 3.5.1.3 Publications

Lefevre & Boers (2009); Maes et al. (2014).

#### 3.5.1.4 References

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### 3.5.2 Marten Network

*Koen Van Den Berge, Jan Gouwy & Filip Berlengee (INBO)*

The *Marten Network* (Marternetwerk) started in 1998 (Van Den Berge 1998) and covers 13 carnivorous species, three of which are non-indigenous (Raccoon, Common raccoon dog and American mink). The protocol mainly consists of collecting and identifying roadkill victims and integrating opportunistic observations. The collected specimens are autopsied with respect to population ecological parameters such as age, reproduction and condition (Van Den Berge 2007a; Van Den Berge 2014). The scheme is coordinated by INBO. Roadkill victims are reported and collected by citizen scientists and autopsied by professional scientists. Data are stored in a local database at INBO and are available on demand. The Marten network currently includes six EU Habitats Directive species (Pine Marten, Western polecat, Eurasian otter, Wildcat, Lynx – Van Den Berge 2007a, Van Den Berge 2014 and Grey wolf – Everaert et al. 2018) and two (Eurasian otter, Lynx) are Annex II & IV species. Two other mammal species (European hamster and Eurasian Beaver) require monitoring according to European legislation but were not covered by any existing monitoring scheme until recently (Table 1).

#### 3.5.2.1 Protocol

Van Den Berge (2007a).

#### 3.5.2.2 Datasets

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#### 3.5.2.3 Publications

Van Den Berge (1997); Van Den Berge (1998); Zoogdierenwerkgroep Jeugdbond voor Natuurstudie en Milieubescherming & Van Den Berge (1999); Van Den Berge et al. (2000); Van Den Berge & Dupae (2001); Van Den Berge et al. (2002); Van Den Berge et al. (2003a); Van Den Berge et al. (2003b); Verkem et al. (2003); Pertoldi et al. (2005); Van Den Berge (2005a); Van Den Berge (2005b); Van Den Berge (2007a); Van Den Berge (2007b); Van Den Berge & Breyne (2007); Holsbeek et al. (2008); Van Den Berge (2008); Beckers et al. (2009); Van Den Berge (2009a); Van Den Berge (2009b); Van Den Berge et al. (2009); Swinnen et al. (2012); Tavernier et al. (2012); Van Den Berge (2012); Van Den Berge et al. (2012); Frantz et al. (2013); Frantz et al. (2014); Maes et al. (2014); Van Den Berge (2014); Adriaens et al. (2015); Baert et al. (2015); Van Den Berge & Gouwy (2015); Van Den Berge et al. (2015); Baert & Van Den Berge (2016); Van Den Berge et al. (2016); Van Den Berge (2017); Van Den Berge et al. (2017); Everaert et al. (2018); Hofmeester et al. (2018); Van Den Berge et al. (2019a); Van Den Berge et al. (2019b); Van Den Berge et al. (2019c); Van der Veken et al. (2019); Everaert et al. (2020); Gouwy & Van Den Berge (2020); Maes et al. (2021a); Maes et al. (2021b); Maes et al. (2021c); Maes et al. (2021d); Maes et al. (2021e); Van Den Berge (2021); Vervaecke et al. (2021); Eeraerts et al. (2022); Van Den Berge et al. (2022a); Van Den Berge et al. (2022b); Larroque et al. (2023); Vada et al. (2023).

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### 3.5.3 Hazel dormouse Monitoring Scheme

*Goedele Verbeylen (Natuurpunt Studie & Natuurpunt Mammal Working Group Flanders)*

In 2003-2007, citizen scientists of the Mammal Working Group of Natuurpunt Studie searched for hazel dormouse signs throughout Flanders (Verbelen et al. 2006; Verbeylen & Nijs 2007). This only confirmed the presence of the species in the municipality of Voeren, where they set up a Hazel dormouse Monitoring Scheme since 2007 (based on Verheggen et al. 2004; Foppen et al. 2007) of searching twice each year (between September 15th and November 15th) for shrub nests in dense edge vegetation along fixed transects (16 in this case – Verbeylen 2009). This citizen scientist work was in some years partially supported by Natuurpunt Studie, provincial, Flemish and municipal governments and INBO. In 2016, INBO adopted the Hazel dormouse Monitoring Scheme as a formal monitoring scheme within Meetnetten.be (De Bruyn et al. 2015). Based on further citizen scientist research in 2013-2018 comparing several monitoring methods, the Mammal Working Group proposed adaptations to the protocol, which were implemented in 2019 (Van Den Berge et al. 2019). Since then, the forests are monitored by checking a standardised set-up of 200 specially designed wooden nest tubes for occupation signs (four times per year: around mid-April, mid-May, end September-early October and end October-early November). This requires less specialisation than searching for shrub nests and is therefore easier to carry out by citizen scientists. Shrub nest searches only continue along three transects along the railway verges, with inclusion of a newly colonised railway part. Data are stored in Meetnetten.be. More detailed data, including additional information collected by the citizen scientists (e.g., on nest and nest site characteristics, see Verbeylen et al. 2017, and habitat quality and changes) are stored in the database of the Mammal Working Group and used to advise on habitat improvement and other protection measures (e.g., by making them available in publications such as Verbeylen & Nijs 2007; Verbeylen et al. 2020).

#### 3.5.3.1 Protocol

Van Den Berge et al. (2019).

#### 3.5.3.2 Datasets

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#### 3.5.3.3 Publications

Verbelen et al. (2006); Verbeylen & Nijs (2007); Verbeylen et al. (2007); Verbeylen (2008a); Verbeylen (2008b); Verbeylen (2009); Verbeylen (2010a); Verbeylen (2010b); Verbeylen (2011); Verbeylen (2012); Verbeylen (2014); Verbeylen et al. (2014a); Verbeylen et al. (2014b); Verbeylen (2015); Verbeylen et al. (2015); Verbeylen et al. (2016a); Verbeylen et al. (2016b); Nijs & Verbeylen (2017); Verbeylen et al. (2017); Verbeylen et al. (2020).

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Hazel dormouse (*Muscardinus avellanarius*), one of the mammals that is monitored in Meetnetten.be (Picture: Rollin Verlinde – Vilda).

## 3.6 PLANTS

### 3.6.1 Florabank

*Wouter Van Landuyt (INBO)*

The *Florabank* started in 1995 and covers all vascular plants and bryophytes in Flanders (2,796 vascular plant species and 532 moss species). It is the continuation of a mapping scheme that started in 1939 and covered the whole of Belgium (Van Rompaey 1943). The majority of the data on vascular plants are collected via plant checklists per square kilometre. The scheme is coordinated by INBO and data are collected by citizen scientists as well as government employed scientists. Data are stored in an online accessible database via a web portal (flora.inbo.be) and have been published on GBIF as the dataset 'Florabank1' for flora checklists from the period 1972-recent and literature and herbaria data from the period 1800-recent and as the dataset 'Belgium IFBL checklists 1939-1971' for the period 1939-1971. The Florabank covers four species of the EU Habitats Directive: one bryophyte species (*Hamatocaulis vernicosus*) and three vascular plant species (*Apium repens*, *Liparis loeselii* & *Luronium natans*). It potentially also yields data on invasive alien plant species of the EU Invasive Alien Species Regulation. For the three vascular plants and the single bryophyte species of the Annex II and IV of the EU Habitats Directive a more detailed monitoring protocol is established (Van Landuyt & Westra 2019).

#### 3.6.1.1 Protocol

Van Landuyt & Westra (2019).

#### 3.6.1.2 Datasets

Van Landuyt & Noé (2018); Van Landuyt & Brosens (2020); Van Landuyt & Brosens (2023); Van Landuyt et al. (2023).

#### 3.6.1.3 Publications

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Creeping marshwort (*Apium repens*), one of the vascular plants that is monitored by Florabank (Picture: Yves Adams – Vilda).

## 3.7 ANIMALS UNDER WHEELS

Sanne Ruyts (Natuurpunt Studie)

*Animals under wheels* started in 2008 (Vercayie et al. 2012). The project is commissioned by the Flemish governement (departement omgeving), coordinated by Natuurpunt Studie and data is collected by citizen scientists. The aim of the project is to map wildlife roadkill in Flanders in order to estimate the amount of wildlife that is killed by traffic in Flanders, to determine the most vulnerable species and to identify and consequently mitigate roadkill hotspots. Citizen scientists submit data on observations of roadkill in the waarnemingen.be database using: (a) the online platform https://waarnemingen.be, (b) the subsite www.dierenonderdewielen. be ('animals under wheels') or (c) the apps ObsMapp for Android, iObs for iPhone and ObsIdentify for all devices. Data consists of both occasional observations and observations along fixed or random transects. Photos of the animals can be added, if available, to support the correct identification of the species. The project focusses on mammals, birds, reptiles and amphibians. Between 1960 and 2020, 89,276 roadkill records were registered from Flanders in the database. Mammals (52,847), birds (23,346) and herpetofauna (11,762) represent 99% of roadkill observations (Swinnen et al. 2022).

#### 3.7.1.1 Protocol

Swinnen et al. 2022.

#### 3.7.1.2 Datasets

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#### 3.7.1.3 Publications

Vercayie et al. 2012; Vercayie & Herremans 2015; Vercayie & Lambrechts 2017; Bíl et al. 2020; Everaert et al. 2020; Jacobs et al. 2021; Swinnen et al. 2022.

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Geoffroy's bat (*Myotis emarginatus*), one of the bats that is monitored in Meetnetten.be (Picture: Rollin Verlinde – Vilda).

# 4 The establishment of an additional monitoring programme to meet monitoring obligations in Flanders

## 4.1 MONITORING OBJECTIVES

A first essential step in the design of monitoring schemes, is to set the monitoring objectives straight (Lindenmayer et al. 2020). The main monitoring objectives are to provide data for the estimation of:

i) Status and trends of the distribution;

ii) Trends in relative abundance;

iii) State of the habitat (area, trend, quality).

In Flanders, information needs for species distributions are largely met by the opportunistic and semi-structured data collected through Waarnemingen.be (Herremans et al. 2018). However, for reliable estimates of trends in (relative) abundance structured data from monitoring schemes are required. In order to design a new monitoring scheme or evaluate an existing one, monitoring objectives needed to be specified by defining the minimal detectable effect size. The reporting guidelines for the EU Habitats Directive state that a population of a species has an unfavourable conservation status if the decline in abundance is larger than 1 % per year (DG Environment 2017). However, it is not clearly specified over which period the trend has to be calculated. Our objective is to detect a decline of 1% per year over a period of 24 years with a statistical power of 80 % at a significance level of 5 %. This corresponds approximately to a total decline in abundance of 25 % over a period of 24 years. Since many target species are characterised by a high natural variability and a low detectability, detecting a smaller effect size (e.g., an average decline of 1% per year during 12 years) was considered not cost-effective. If larger declines occur they will be spotted much earlier than the 24$^{th}$ monitoring year. For example, Westra et al. (2014) estimated that a total decline of 80 % can be detected in 10 years.

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## 4.2 EVALUATION OF ESTABLISHED MONITORING SCHEMES

Before designing new monitoring schemes, it is of great importance to make maximum use of established monitoring schemes and data (cf. van Swaay & van Strien 2008). Most of these schemes in Flanders (i.e., with more than 10 years of data) were screened and evaluated for their effectiveness, data requirements and quality, statistical power using international criteria (cf. Legg & Nagy 2006; Lindenmayer et al. 2020) and local requirements (Onkelinx et al. 2008). Wherever necessary, the existing schemes were adjusted to make them more cost-effective and/or cost-efficient by changing the number of sampling points or the sampling frequency to meet the required standards (e.g., Geeraerts & Quataert 2012).

## 4.3 DEVELOPMENT OF NEW MONITORING SCHEMES

A joint analysis by the Research institute for Nature and Forest (INBO) and the Agency for Nature and Forests (ANB) of the Flemish Government in 2013 revealed that a total of 85 Flemish species with monitoring obligations were not or only partially covered by existing monitoring schemes. For 16 of these species (15 EU Habitats Directive species and one Flemish Priority Species) monitoring was considered not feasible and ineffective at that time (Table 1). For the remaining 69 species a new monitoring programme called Meetnetten.be was designed in 2014 (De Knijf et al. 2014) and started in 2016. It was especially designed to monitor EU Habitats Directive species (n = 22) and Flemish Priority Species (n = 50) (Westra et al. 2016). Three species, Eurasian badger *Meles meles*, the Gatekeeper butterfly (*Pyronia tithonus*), the Hazel dormouse (*Muscardinus avellanarius*) and wintering bats, were already included in existing monitoring schemes, but were also incorporated in the new monitoring programme after the necessary adjustments to their monitoring schemes. An important criterion for the design of the new monitoring schemes was that they had to be executed by citizen scientists.

The following workflow and decision scheme was applied for the design of the new monitoring schemes (Figure 2):

1) Distribution data were compiled from all available data sources (mostly Waarnemingen.be, managed by Natuurpunt Studie). This provided the basis for the sampling frame (see further);

2) For nine species (three beetle species, one mammal, four mollusc and one spider species), the distribution proved insufficiently known. As sufficient knowledge of the species distribution is a prerequisite to start a large scale monitoring scheme, field protocols including targeted surveys of potentially suitable habitats were generated and applied (Maes et al. 2017). Once the distribution of these species is sufficiently known, they can be included in a monitoring scheme;

4) For the remaining 63 species, a sampling frame was compiled consisting of sites with known (clusters of) populations. Sites were identified as follows:
    a. for terrestrial species, actual populations were delineated based on the distribution data and field knowledge;
    b. for aquatic species (e.g., Great crested newt *Triturus cristatus*, European tree frog *Hyla arborea*, Pool frog *Pelophylax lessonae*, Moor frog *Rana arvalis*), populations were identified by combining distribution data from citizen scientists with a GIS map covering all water bodies in Flanders (Packet et al. 2018b).

5) Selection of (number of) monitoring sites:
    a. if the number of sites in the sampling frame was <60, all sites were ultimately selected as monitoring sites, which is referred to as *census monitoring* (51 species); species are monitored in all of these sites on a yearly basis;
    b. if the number of sites in the sampling frame was >60, 30-60 monitoring sites (depending on the taxonomic group) were selected from the sampling frame (12 species) using a Generalised Random Tessellation Stratified sampling strategy (GRTS – Stevens & Olsen 2003). This technique generates an ordered list of sites by assigning a random GRTS ranking number (from 1 to 60) to each site in the sampling frame, while assuring a spatially-balanced design. When a sample of, e.g., 60 sites is required, the 60 sites with the lowest GRTS ranking number are selected for the monitoring scheme. GRTS allows to immediately select a new site whenever a site is no longer relevant (e.g., no longer occupied by the species or becoming inaccessible during the monitoring period), by taking the next site (61st) according to the GRTS ranking (Onkelinx & Quataert 2014). This preserves the stratified random site distribution of the monitoring sites. Common species are usually counted in a staggered three-year cycle with approximately one third of all sites counted each year.

6) Standardised observation techniques were developed or existing ones adopted or adjusted for each species. These monitoring protocols describe in detail what, how and when to count while taking into account the feasibility of the counting by citizen scientists. The number of visits per site within one season ranges from one visit (vascular plants) to six visits (for example the dragonfly River clubtail *Stylurus flavipes* and the Wall Brown butterfly *Lasiommata megera*). The following monitoring techniques were distinguished:
    a. area/site counts (counting all adult individuals, pairs or territories) for frogs and toads, bats, breeding birds (e.g., Gilbert et al. 2012), butterflies, dragonflies, grasshoppers, mosses, wintering water birds and vascular plants (i.e., counting the number of individuals during a certain time in a delimited area or occupied area in m² for clonal plants);
    b. transect counts (i.e., counting the number of individuals along a fixed transect) for Fire salamander *Salamandra salamandra*, Stag beetle *Lucanus cervus*, butterflies (e. g. Sevilleja et al. 2019), dragonflies and spiders;
    c. depletion counts (i.e., counting all individuals collected on a site per unit of time) for grasshoppers (e.g., Schori et al. 2020);
    d. exuviae counts (i.e., counting and removing the empty larval skins of dragonflies in a delimited area along a transect at the bank of a canal) for the River clubtail *Stylurus flavipes* (e.g., Hardersen et al. 2017) or along a stream or river for the Common clubtail (*Gomphus vulgatissimus*);
    e. pheromone traps (i.e., using female pheromones to attract and count males of elusive species) for the Rusty click beetle *Elater ferrugineus* (e.g., Turchin & Odendaal 1996; Larsson 2016);
    f. egg counts (i.e., counting the number of eggs in a delimited area) for the Alcon blue butterfly *Phengaris alcon* (Van Dyck & Regniers 2010);
    g. sett counts for Eurasian badger (*Meles meles*) and European hamster (*Cricetus cricetus* (Wilson et al. 2003);
    h. nest counts (i.e., searching for shrub nests in dense edge vegetation along fixed transects in autumn – Verheggen et al. 2004; Foppen et al. 2007; Verbeylen 2008; Verbeylen 2009) and nest tube checks (i.e., checking for occupation signs such as nests, animals, droppings and feeding remains in a standardised set-up of wooden

tubes – Van Den Berge et al. 2019) for the Hazel dormouse *Muscardinus avellanarius*;

i. tracks and spraints detection for the Eurasian otter *Lutra lutra* (Reuther et al. 2000);

j. funnel traps (i.e., counting the number of individuals caught in the trap in a given time) for the Great crested newt *Triturus cristatus* (Griffiths 1985).

7) Newly developed observation techniques were first tested in a pilot phase to evaluate its cost-effectiveness and its applicability by volunteers. An example is the evaluation of pheromone traps for the Rusty click beetle *Elater ferrugineus.*

8) Smartphone applications and a web portal (Meetnetten.be) were developed for data entry during and/or after field work; the database that supports the portal also allows data storage and reporting. Citizen scientists who want to participate, can apply for one of the monitoring schemes (see further). Once accepted they can claim a monitoring site and execute a number of monitoring-related tasks.

9) Publish monitoring data on GBIF: most datasets comprising monitoring results collected during the period 2016-2022 have been published (see https://www.gbif.org/dataset/search?project_id=meetnetten.be). The datasets are updated on a yearly basis.

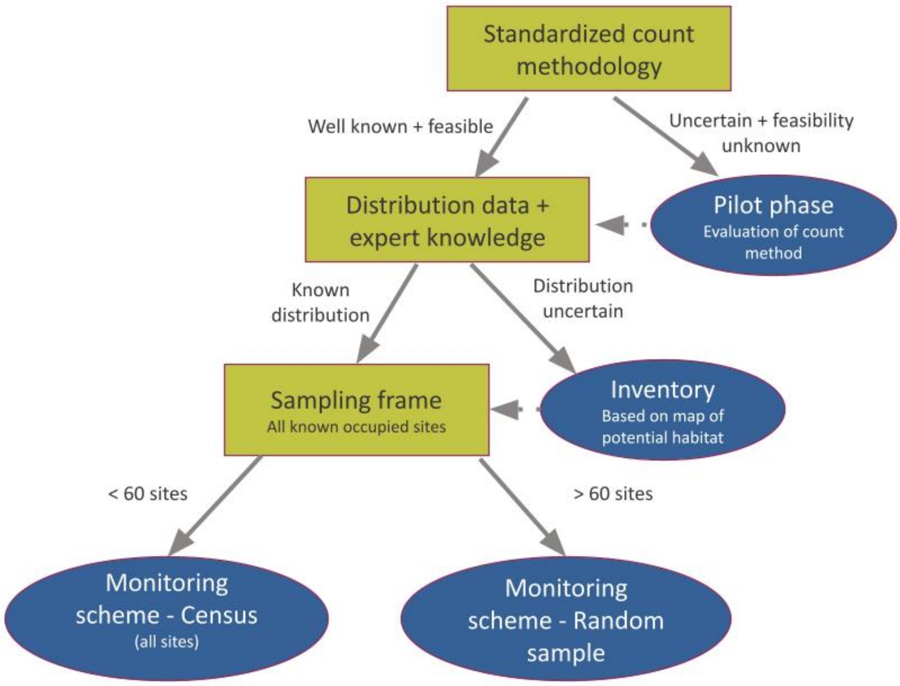


Figure 2 Decision tree and workflow for the design of new monitoring schemes in Flanders.

For each monitoring scheme (mostly taxon-based), both the site selection and the standardised observation technique are documented in so-called monitoring protocols (Table 2). Based on the monitoring protocols the monitoring schemes, including distribution update inventories for nine species (see above), were successfully implemented between 2016 and 2022.

Table 2 References to the most recent version of the monitoring protocols for the different taxonomic groups in Meetnetten.be. The number of species that is treated in the respective protocol is given between brackets.

| Species group | Reference |
|---|---|
| Amphibians & Reptiles (9) | Speybroeck et al. (2020) |
| Beetles (3) | Thomaes et al. (2019) |
| Butterflies (12) | Maes et al. (2019) |
| Dragonflies (11) | De Knijf et al. (2019) |
| Grasshoppers (2) | De Knijf et al. (2016) |
| Mammals (4) | Van Den Berge et al. (2019) |
| Molluscs (2) | Packet et al. (2018a) |
| Spiders (2) | Van Keer et al. (2020) |
| Vascular plants (24) | Van Landuyt & Westra (2019) |

## 4.4 COORDINATION, EXECUTION AND REPORTING

For each monitoring scheme, different *bodies* are defined, each with a specific role (cf. Scholes et al. 2017):

- a direction-setting body;
- an executing body;
- a data-storage body;
- a reporting body.

### 4.4.1 Direction-setting body

In collaboration with the stakeholders (future users of the monitoring results) the direction-setting body decides on the monitoring priorities and eventually the monitoring goals (i.e., which species and locations to monitor, the monitoring frequency and methods), the monitoring strategy and the monitoring type (i.e., structured versus unstructured), and if structured, the sampling design and the monitoring protocol. It also determines the available budget and the implementation. In 2015, the Research Institute for Nature and Forest (INBO) and the Agency for Nature and Forest (ANB) decided to launch the long-term monitoring from 2016 onwards in 5-yearly cycles. At the end of each monitoring cycle, the direction-setting body evaluates the results of the accomplished monitoring programme, takes into account new emerging needs and designs an adjusted programme for the next five years. In Flanders, INBO and ANB take on the direction-setting role for the Meetnetten.be monitoring programme.

### 4.4.2 Executing body

The executing body coordinates the execution of the monitoring actions by recruiting, training and supporting citizen scientists. The executing body also converts the scientific monitoring protocols (generated by researchers) into practical field manuals. These manuals explain citizen scientists how to apply the field protocol, how to use maps and data collection forms and/or the mobile application to register all the required data. It also provides information on e.g., how to distinguish similar species and their different life stages (e.g., larvae or eggs Great crested newt *Triturus cristatus* vs. other newt larvae) and the traces they leave behind (e.g., tracks, spraints or nests). In addition, this body deals with a first overall data quality check. This body is also responsible for achieving the annual goals agreed upon at the start of every season together with the direction-setting body. In Flanders, most of the data are collected by trained citizen scientists, co-ordinated by Natuurpunt Studie. Apart from some very rare exceptions (e.g., highly specialised experts that need to visit remote areas), the citizen scientists are not paid for their work, but the necessary material is provided by Natuurpunt Studie which receives financial support by INBO and ANB for its coordination role. Only a few schemes (Fish Monitoring Scheme, Florabank – systematic inventories of all higher plant species – and Marten Network) are organised and executed by professional researchers and associated field workers, mostly employed by the Flemish government (i.e., INBO). Coordinators of the executing body operate in close collaboration with the direction-setting body (i.e., INBO). In addition, a steering committee composed of representatives of INBO, ANB and Natuurpunt Studie supervises the activities.

At the end of each monitoring season or year, each species monitoring protocol is thoroughly evaluated by the executing body and, if relevant, proposals for adjustments submitted and discussed with the direction-setting body (INBO). These changes can imply, for example, replacing a monitoring site that became unsuitable during the season or additional visits in case of an occasional third generation in some butterfly species. As feasibility by citizen scientists is of key importance in this monitoring programme, some protocols were replaced by more appropriate ones for citizen scientists.

### 4.4.3 Data-storage body

The data-storage body is responsible for the structured storage and accessibility of the monitoring data, but also carries out a thorough exploration, quality control, analysis and publication of the monitoring data. In Flanders, INBO is in charge of the management of the database of these long-term monitoring schemes and is principal owner of these data, together with the individual citizen scientists. The portal Meetnetten.be is the repository for nearly all these data. Data on a few species that cannot yet be stored in the Meetnetten.be database, are retrieved from other sources and provided by the executing body at the end of each monitoring season.

### 4.4.4 Reporting body

The reporting body is responsible for the transmission of the monitoring results to the respective authorities of the different conventions such as for the Article 12 and 17 reporting of EU Birds and Habitats Directive, respectively. In Flanders, the governmental Agency for Nature and Forests (ANB) takes on this role for most of the European conventions, supported by INBO.

## 4.5 FUNDING

These new monitoring schemes are co-financed by the Research Institute for Nature and Forest (INBO) and the Agency for Nature and Forests (ANB). This covers the coordination by the execution body for both the new monitoring schemes and the established monitoring schemes for birds and bats. Furthermore, INBO staff contribute to the monitoring programme for a total workload of approximately two fulltime equivalents. The staff includes a program manager, a project leader, species experts (monitoring protocols and reporting), statisticians (monitoring design and data analysis) and data scientists (data management and data publication).

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Green-winged orchid (*Orchis morio*), one of the vascular plants that is monitored in Meetnetten.be (Picture: Rollin Verlinde – Vilda).

## 4.6 THE MONITORING SCHEMES IN MEETNETTEN.BE

### 4.6.1 General

*Toon Westra, Frederic Piesschaert, Marc Pollet (INBO) & Hannes Ledegen, Sam Van de Poel (Natuurpunt Studie)*

The new monitoring schemes in Meetnetten.be started since 2016 (Westra et al. 2016), but may have different starting years for different species. In Figure 3, we give an overview of the species for which Flanders has monitoring obligations and by which monitoring scheme they are covered.

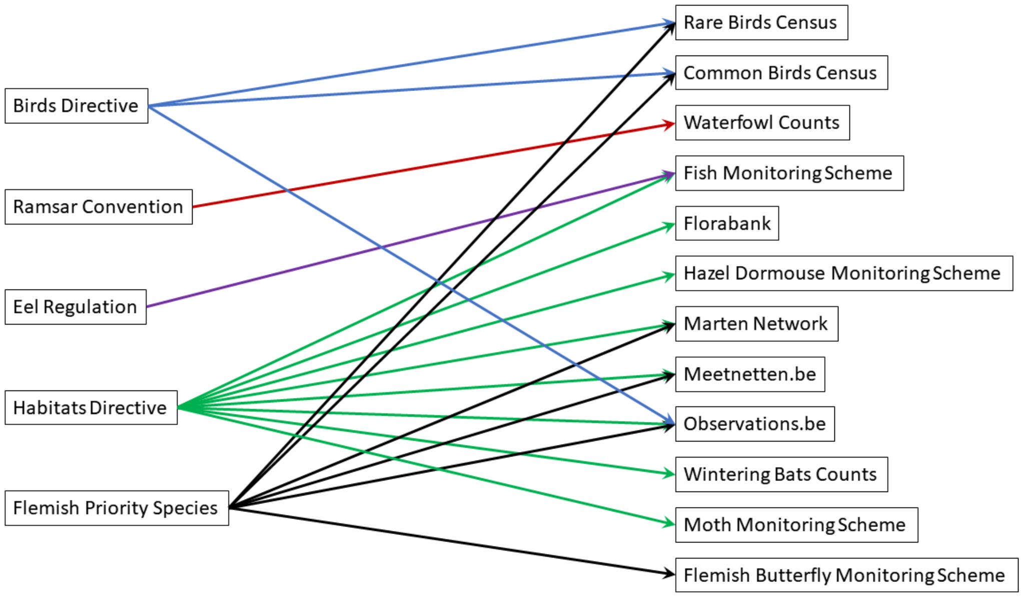


Figure 3 Monitoring obligations for species of conservation concern (left) and schemes (right) that cover the monitoring obligations in Flanders.

#### 4.6.1.1 Publications

Westra et al. (2016); Onkelinx et al. (2017); Westra et al. (2019).

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## 4.6.2 Plants

### 4.6.2.1 Vascular plants

*Wouter Van Landuyt & An Leyssen (INBO)*

Three vascular plant species are on the European Habitats Directive and a further 24 are Flemish Priority Species (Table 3).

Table 3 Vascular plants monitored in Meetnetten.be. Leg. = Legislation. EPS = European Priority Species (HD II = Habitats Directive Annex II species), FPS = Flemish Priority Species.

| **Species** | **English name** | **Dutch name** | **Leg.** |
|---|---|---|---|
| *Apium repens* | Creeping marshwort | Kruipend moesrasscherm | EPS (HD II) |
| *Bupleurum tenuissimum* | Slender hare's-ear | Fijn goudscherm | FPS |
| *Carex diandra* | Lesser tussock-sedge | Ronde zegge | FPS |
| *Deschampsia setacea* | Bog hair-grass | Moerassmele | FPS |
| *Diphasiastrum tristachyum* | Blue ground-cedar | Kleine wolfsklauw | FPS |
| *Eriophorum gracile* | Slender cottongrass | Slank wollegras | FPS |
| *Gentianella uliginosa* | Dune gentian | Duingentiaan | FPS |
| *Halimione pedunculata* | Pedunculate sea-purslane | Gesteelde zoutmelde | FPS |
| *Hammarbya paludosa* | Bog orchid | Veenmosorchis | FPS |
| *Herminium monorchis* | Musk orchid | Honingorchis | FPS |
| *Juncus capitatus* | Dwarf rush | Koprus | FPS |
| *Liparis loeselli* | Fen orchid | Groenknolorchis | EPS (HD II) |
| *Luronium natans* | Floating water-plantain | Drijvende waterweegbree | EPS (HD II) |
| *Mentha pulegium* | Pennyroyal | Polei | FPS |
| *Orchis morio* | Green-winged orchid | Harlekijn | FPS |
| *Orchis purpurea* | Lady orchid | Purperorchis | FPS |
| *Orobanche rapum-genistae* | Greater broomrape | Grote bremraap | FPS |
| *Platanthera bifolia* | Lesser butterfly orchid | Welriekende nachtorchis | FPS |
| *Potamogeton acutifolius* | Sharp-leaved pondweed | Spits fonteinkruid | FPS |
| *Potamogeton coloratus* | Fen pondweed | Weegbreefonteinkruid | FPS |
| *Potamogeton compressus* | Grasswrack pondweed | Plat fonteinkruid | FPS |
| *Ranunculus ololeucos* | White flowered buttercup | Witte waterranonkel | FPS |
| *Schoenoplectus pungens* | Sharp club-rush | Stekende bies | FPS |
| *Schoenoplectus triqueter* | Triangular club-rush | Driekantige bies | FPS |
| *Scorzonera humilis* | Viper's grass | Kleine schorseneer | FPS |
| *Stratiotes aloides* | Water doldier | Krabbenscheer | FPS |
| *Wahlenbergia hederacea* | Ivy-leaved bellflower | Klimopklokje | FPS |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of plants are given in Table 4.

Table 4 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for vascular plants in Meetnetten.be. stY = starting year; Type: I = integral; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: A = area in m², I = number of individuals.

| **Species** | **StY** | **Type** | **#loc/y** | **Cycle** | **#vis/y** | **Meth** |
|---|---|---|---|---|---|---|
| *Apium repens* | 2008 | I | 8 | 3 | 1 | A |
| *Bupleurum tenuissimum* | 2016 | I | 1 | 3 | 1 | I |
| *Carex diandra* | 2016 | I | 7 | 3 | 1 | A |
| *Deschampsia setacea* | 2016 | I | 3 | 3 | 1 | A |
| *Diphasiastrum tristachyum* | 2016 | I | 2 | 3 | 1 | I |
| *Eriophorum gracile* | 2016 | I | 4 | 3 | 1 | A |
| *Gentianella uliginosa* | 2016 | I | 13 | 3 | 1 | I |
| *Halimione pedunculata* | 2016 | I | 2 | 3 | 1 | A |
| *Hammarbya paludosa* | 2016 | I | 1 | 3 | 1 | I |
| *Herminium monorchis* | 2016 | I | 13 | 3 | 1 | I |
| *Juncus capitatus* | 2016 | I | 1 | 3 | 1 | I |
| *Liparis loeselli* | 2008 | I | 3 | 3 | 1 | I |
| *Luronium natans* | 2008 | I | 15 | 6 | 1 | A+ |
| *Mentha pulegium* | 2016 | I | 3 | 3 | 1 | A |
| *Orchis morio* | 2016 | I | 3 | 3 | 1 | I |
| *Orchis purpurea* | 2016 | I | 11 | 3 | 1 | I |
| *Orobanche rapum-genistae* | 2016 | I | 37 | 3 | 1 | I |
| *Platanthera bifolia* | 2016 | I | 14 | 3 | 1 | I |
| *Potamogeton acutifolius* | 2016 | I | 13 | 3 | 1 | A |
| *Potamogeton coloratus* | 2016 | I | 12 | 3 | 1 | A |
| *Potamogeton compressus* | 2016 | I | 3 | 3 | 1 | A |
| *Ranunculus ololeucos* | 2016 | I | 49 | 3 | 1 | A |
| *Schoenoplectus pungens* | 2016 | I | 3 | 3 | 1 | A |
| *Schoenoplectus triqueter* | 2016 | I | 12 | 3 | 1 | A |
| *Scorzonera humilis* | 2016 | I | 6 | 3 | 1 | I |
| *Stratiotes aloides* | 2016 | I | 3 | 3 | 1 | I |
| *Wahlenbergia hederacea* | 2016 | I | 8 | 3 | 1 | A |

#### 4.6.2.1.1 Protocol

Van Landuyt & Westra (2019); Leyssen (2022).

#### 4.6.2.1.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2022b).

#### 4.6.2.1.3 Publications

Spanoghe et al. (2008); Van Landuyt & T'jollyn (2011); Van Landuyt et al. (2014); Van Landuyt et al. (2015); Van Landuyt et al. (2019); Van Landuyt & T'jollyn (2022).

### 4.6.2.1.4 References


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Van Landuyt W, Gyselings R, T'jollyn F & Vanden Broeck A. (2014). Groenknolorchis (*Liparis loeselii*) in Vlaanderen: ecologie, populatiedynamica en potenties. Rapporten van het Instituut voor Natuur- en Bosonderzoek INBO.R.2014.2942320. Brussel: Instituut voor Natuur- en Bosonderzoek.

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Van Landuyt W & T'jollyn F. (2022). Monitoring van kruipend moerasscherm (*Helosciadium repens*) in Vlaanderen. Resultaten uit de periode 2008-2020. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2022 (11). Brussel: Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.55010824

Van Landuyt W & Westra T. (2019). Monitoringsprotocol Vaatplanten en Mossen, versie 2.0. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (47). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.17097948

#### 4.6.2.2 Mosses

*Wouter Van Landuyt (INBO)*

One moss species is on the European Habitats Directive (Table 5).

Table 5 Mosses monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II: Annex II species of the Habitats Directive).

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Hamatocaulis vernicosus* | Slender green feather-moss | Geel schorpioenmos | EPS (HD II) |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods are given in Table 6.

Table 6 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for mosses in Meetnetten.be. stY = starting year; Type: I = integral; #loc/y: number of locations per year; Cycle: 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: Meth = method (A = area in m²).

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Hamatocaulis vernicosus* | 2008 | I | 3 | 3 | 1 | A |

##### 4.6.2.2.1 Protocol

Van Landuyt & Westra (2019).

##### 4.6.2.2.2 Datasets

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##### 4.6.2.2.3 Publications

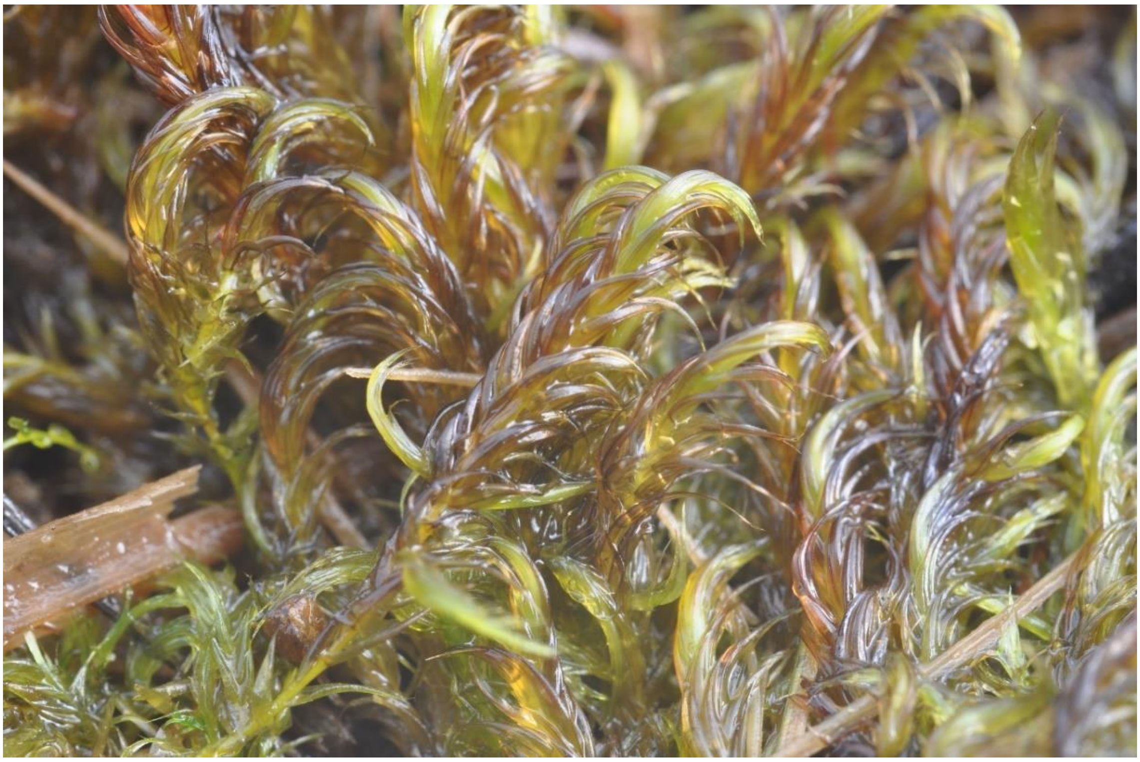
De Beer (2017); Van Landuyt et al. (2019).

##### 4.6.2.2.4 References

De Beer D (2017) De heropstanding van *Hamatocaulis vernicosus* in de Antwerpse Kempen. Dumortiera 110: 19-21.

Van Landuyt W, Leyssen A & Denys L. (2019). Staat van instandhouding (status en trends) van de soorten van de Habitatrichtlijn. Deelrapport korstmossen, mossen en vaatplanten (rapportageperiode 2013-2018). Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (17). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.16136169

Van Landuyt W & Westra T. (2019). Monitoringsprotocol Vaatplanten en Mossen, versie 2.0. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (47). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.17097948



Varnished hook-moss (*Hamatocaulis vernicosus*), one of the mosses that is monitored in the Florabank project (Picture: Wouter Van Landuyt – INBO).

### 4.6.3 Amphibians and reptiles

*Jeroen Speybroeck (INBO)*

Eight amphibian and one reptile species are either on the European Habitats Directive or are Flemish Priority Species and are included in Meetnetten.be (Table 7).

Table 7 Amphibians and reptiles monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II, IV: Annex II, IV species of the Habitats Directive); FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Alytes obstetricans* | Midwife toad | Vroedmeesterpad | EPS (HD IV) |
| *Bufo calamita* | Natterjack toad | Rugstreeppad | EPS (HD IV) |
| *Coronella coronella* | Smooth snake | Gladde slang | EPS (HD IV) |
| *Hyla arborea* | European tree frog | Boomkikker | EPS (HD IV) |
| *Pelobates fuscus* | Common spadefoot toad | Knoflookpad | EPS (HD IV) |
| *Pelophylax lessonae* | Pool frog | Poelkikker | EPS (HD IV) |
| *Rana arvalis* | Moor frog | Heikikker | EPS (HD IV) |
| *Salamandra salamandra* | Fire salamander | Vuursalamander | FPS |
| *Triturus cristatus* | Crested newt | Kamsalamander | EPS (HD II+IV) |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of amphibians and reptiles are given in Table 8.

Table 8 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for amphibians and reptiles in Meetnetten.be. stY = Starting year; Type = Type of monitoring (I = Integral; PP = Pilot phase; S = Subsample); #loc/y: number of locations per year; Cycle: yearly cycle (1 = every year, 3 = 3-year cycle); #vis/y = number of visits per year; Meth = method (C = calls of males; E = eggs; F = fykes; N = netting of juveniles/larvae; AS = artificial substrates ('tins'), T = transects).

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Alytes obstetricans* | 2022 | S | 15 | 1 | 3+1 | C+N |
| *Coronella coronella* | 2021 | PP | 49 | 1 | 7 | AS |
| *Epidalea calamita* | 2019 | I | 16 | 3 | 3 | T+C+E |
| *Hyla arborea* | 2016 | S | 20 | 3 | 2+1 | C+N |
| *Pelobates fuscus* | 2017 | I | 6 | 1 | 2 | C |
| *Pelophylax lessonae* | 2021 | S | 20 | 3 | 2+1 | C+N |
| *Rana arvalis* | 2021 | S | 20 | 3 | 2 | E |
| *Salamandra salamandra* | 2016 | I | 32 | 1 | 2 | T |
| *Triturus cristatus* | 2017 | S | 20 | 3 | 2+1 | F+N |

#### 4.6.3.1 Protocol

Speybroeck et al. (2020).

#### 4.6.3.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2022b); Piesschaert et al. (2022c); Piesschaert et al. (2022d); Piesschaert et al. (2022e)

#### 4.6.3.3 Publications

De Bruyn et al. (2015a); De Bruyn et al. (2015b); De Bruyn et al. (2015c); Speybroeck & De Knijf (2019); Beukema et al. (2021).

#### 4.6.3.4 References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Piesschaert F, Speybroeck J, Brosens D, Westra T, Desmet P, Ledegen H, Van de Poel S & Pollet M (2022b). Meetnetten.be - Fyke counts for Amphibia in Flanders, Belgium. Version 1.12. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/zeaq2t

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Piesschaert F, Speybroeck J, Brosens D, Westra T, Desmet P, Ledegen H, Van de Poel S & Pollet M (2022d). Meetnetten.be - Sightings for Natterjack toad in Flanders, Belgium. Version 1.12. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/2xfw8y

Piesschaert F, Speybroeck J, Brosens D, Westra T, Desmet P, Ledegen H, Van de Poel S & Pollet M (2022e). Meetnetten.be - Transects for fire salamanders in Flanders, Belgium. Version 1.11. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/nbsk9h

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Speybroeck J & De Knijf G. (2019). Staat van instandhouding (status en trends) van de soorten van de Habitatrichtlijn. Deelrapport amfibieën en reptielen (rapportageperiode 2013-2018). Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (12). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.16089660

Midwife toad (*Alytes obstetricans*), one of the amphibians that is monitored in Meetnetten.be (Picture: Lars Soerink - Vilda).

Smooth snake (*Coronella coronella*), the only reptile that is monitored in in Meetnetten.be (Picture: Yves Adams – Vilda).

### 4.6.4 Beetles

*Arno Thomaes (INBO)*

Four beetle species are either on the European Habitats Directive or are Flemish Priority Species. Three species are monitored in Meetnetten.be and for one species (Hermit beetle) an update of the distribution is needed before we can start up a monitoring scheme (Table 9). The monitoring of the Stag beetle in Flanders already started in 2012 and became part of the European Stag Beetle Monitoring Network (ESBMN) since this was funded in 2016 (Thomaes et al. 2021a). Therefore, the data is compiled via the ESBMN and not in Meetnetten.be.

Table 9 Beetles monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II: Annex II species of the Habitats Directive); FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Cucujus cinnaberinus* | Red flat bark beetle | Vermiljoenkever | EPS (HD II) |
| *Elater ferrugineus* | Rusty click beetle | Roestbruine kniptor | FPS |
| *Lucanus cervus* | Stag beetle | Vliegend hert | EPS (HD II) |
| *Osmoderma eremita** | Hermit beetle | Juchtleerkever | EPS (HD II+IV) |

* This species is not yet included in the Meetnetten.be monitoring scheme

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of beetles are given in Table 10.

Table 10 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for beetles in Meetnetten.be. stY = Starting year; Type: PP = Pilot phase, S = subsample, I = integral; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = Method: DT = surveying dead trees, F = pheromone traps, T = Transects, UD = Update distribution.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Cucujus cinnaberinus* | 2021 | PP | 30 | 3 | 1 | DT |
| *Elater ferrugineus* | 2018 | S | 30 | 3 | 2 | F |
| *Lucanus cervus* | 2017 | I | 18 | 1 | 5-8 | T |
| *Osmoderma eremita* | - | - | - | - | - | UD |

#### 4.6.4.1 Protocol

Thomaes et al. (2019).

#### 4.6.4.2 Datasets

Thomaes et al. (2023).

#### 4.6.4.3 Publications

Thomaes (2014); Campanaro et al. (2016); Thomaes et al. (2016); Thomaes et al. (2017); De Knijf et al. (2019); Thomaes et al. (2019); Thomaes et al. (2021a); Thomaes et al. (2021b); Thomaes et al. (2022); Sikora et al. 2023.

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Thomaes A, Barbalat S, Bardiani M, Bower L, Campanaro A, Soutinho JG, Harvey D, Hawes C, Kadej M, Méndez M, Rink M, Rossi De Gasperis S, Ruyts S, Šerić Jelaska L, Smit J, Smolis A, Vrezec A & Brosens D (2023). European stag beetle monitoring network: transect observations. Version 1.9. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/j69hbu

Thomaes A, Crévecoeur L, Daka G, De Block M, Fievet V, Heyndrickx R, Kariuki K, Lammerant R, Marchand S, Scheers K, Smeekens V & Van De Kerckhove P (2021b) *Cucujus cinnaberinus* (Cucujidae) is rapidly colonising Northern Belgium. Bulletin de la Société royale belge d'Entomologie / Bulletin van de Koninklijke Belgische Vereniging voor Entomologie 157 (3): 162–172.

Thomaes A, Ledegen H & Westra T. (2019). Monitoringsprotocol kevers: Versie 2.0. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (54). Brussel: Instituut voor Natuur- en Bosonderzoek. http://doi.org/10.21436/inbor.17397655

Thomaes A, Maes D, Onkelinx T, De Knijf G & Ledegen H. (2016). Monitoringsprotocol kevers. Rapporten van het Instituut voor Natuur- en Bosonderzoek INBO.R.2016.11505527. Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.11505527

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Thomaes A, Verschelde P, Mader D, Sprecher-Uebersax E, Fremlin M, Onkelinx T & Méndez M (2017) Can we successfully monitor a population density decline of elusive invertebrates? A statistical power analysis on *Lucanus cervus*. Nature Conservation 19. https://doi.org/10.3897/natureconservation.19.11761

Red flat bark beetle (*Cucujus cinnaberinus*), one of the beetles that is monitored in Meetnetten.be (Picture: Jeroen Mentens - Vilda).

### 4.6.5 Butterflies

*Dirk Maes (INBO)*

One butterfly species is on the European Habitats Directive (Marsh fritillary) and 11 other species are Flemish Priority Species (Table 11).

Table 11 Butterflies monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II: Annex II species of the Habitats Directive); FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Apatura iris* | Purple emperor | Grote weerschijnvlinder | FPS |
| *Cyaniris semiargus* | Mazarine blue | Klaverblauwtje | FPS |
| *Erynnis tages* | Dingy skipper | Bruin dikkopje | FPS |
| *Euphydryas aurinia* | Marsh fritillary | Moerasparelmoervlinder | EPS (HD II) |
| *Hesperia comma* | Silver-spotted skipper | Kommavlinder | FPS |
| *Hipparchia semele* | Grayling buttefly | Heivlinder | FPS |
| *Lasiommata megera* | Wall brown | Argusvlinder | FPS |
| *Melitaea cinxia* | Glanville fritillary | Veldparelmoervlinder | FPS |
| *Phengaris alcon* | Alcon blue | Gentiaanblauwtje | FPS |
| *Pyrgus malvae* | Grizzled skipper | Aardbeivlinder | FPS |
| *Pyronia tithonus* | Gatekeeper | Oranje zandoogje | FPS |
| *Satyrium ilicis* | Ilex hairstreak | Bruine eikenpage | FPS |

The starting year, type of monitoring, number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of butterflies are given in Table 12.

Table 12 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for butterflies in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: T = transect count, S = site count, E = egg count.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Apatura iris* | 2016 | I | 20-25 | 1 | 3 | S |
| *Cyaniris semiargus* | 2017 | I | 5-7 | 1 | 6 | T |
| *Erynnis tages* | 2017 | I | 4 | 1 | 6 | T |
| *Euphydryas aurinia* | 2020 | I | 1 | 1 | 3 | T |
| *Hesperia comma* | 2016 | I | 11 | 1 | 3 | T |
| *Hipparchia semele* | 2016 | S | 10 | 3 | 3 | T |
| *Lasiommata megera* | 2016 | S | 10 | 3 | 6 | T |
| *Melitaea cinxia* | 2016 | I | 11 | 1 | 3 | T |
| *Phengaris alcon* | 2016 | I | 7 | 1 | 1 | E |
| *Pyrgus malvae* | 2017 | I | 4 | 1 | 3 | T |
| *Pyronia tithonus* | 2017 | S | 10 | 3 | 3 | T |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Satyrium ilicis* | 2018 | I | 13 | 1 | 3 | S |

#### 4.6.5.1 Protocol

Maes et al. (2019).

#### 4.6.5.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2022b); Piesschaert et al. (2022c).

#### 4.6.5.3 Publications

De Knijf et al. (2019); Westra et al. (2022a); Westra et al. (2022b).

#### 4.6.5.4 References

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### 4.6.6 Dragonflies

*Geert De Knijf (INBO)*

Three dragonfly species are on the European Habitats Directive (River clubtail, Lilypad whiteface and Large whiteface) and eight more species are Flemish Priority Species (Table 13).

Table 13 Dragonflies monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II, IV: Annex II, IV species of the Habitats Directive); FPS = Flemish Priority Species.

| **Species** | **English name** | **Dutch name** | **Leg.** |
|---|---|---|---|
| *Aeshna isoceles* | Green-eyed hawker | Vroege glazenmaker | FPS |
| *Calopteryx virgo* | Beautiful demoiselle | Bosbeekjuffer | FPS |
| *Coenagrion hastulatum* | Northern damselfly | Speerwaterjuffer | FPS |
| *Coenagrion lunulatum* | Irish damselfly | Maanwaterjuffer | FPS |
| *Coenagrion pulchellum* | Variable damselfly | Variabele waterjuffer | FPS |
| *Stylurus flavipes* | River clubtail | Rivierrombout | EPS (HD IV) |
| *Gomphus vulgatissimus* | Common clubtail | Beekrombout | FPS |
| *Leucorrhinia caudalis* | Lilypad whiteface | Sierlijke witsnuitlibel | EPS (HD IV) |
| *Leucorrhinia pectoralis* | Large whiteface | Gevlekte witsnuitlibel | EPS (HD II+IV) |
| *Somatochlora arctica* | Northern emerald | Hoogveenglanslibel | FPS |
| *Sympetrum depressiusculum* | Spotted darter | Kempense heidelibel | FPS |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of dragonflies are given in Table 14.

Table 14 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for dragonflies in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: ET = exuviae count along a transect, S = site count T = transect count.

| **Species** | **stY** | **Type** | **#loc/y** | **Cycle** | **#vis/y** | **Meth** |
|---|---|---|---|---|---|---|
| *Aeshna isosceles* | 2017 | S | 10 | 3 | 3 | T |
| *Calopteryx virgo* | 2018 | S | 10 | 3 | 3 | T |
| *Coenagrion hastulatum* | 2017 | I | 5 | 1 | 2 | S |
| *Coenagrion lunulatum* | 2016 | I | 7 | 1 | 2 | S |
| *Coenagrion pulchellum* | 2017 | S | 10 | 3 | 2 | T |
| *Stylurus flavipes* | 2016 | S | 10 | 1 | 6 | ET |
| *Gomphus vulgatissimus* | 2018 | I | 4 | 1 | 3 | ET |
| *Leucorrhinia caudalis* | 2020 | I | 2 | 1 | 2 | S |
| *Leucorrhinia pectoralis* | 2016 | I | 25 | 1 | 2 | S |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Somatochlora arctica* | 2018 | I | 12 | 2 | 2 | S |
| *Sympetrum depressiusculum* | 2016 | I | 5 | 1 | 2 | S |

#### 4.6.6.1 Protocol

De Knijf et al. (2019a).

#### 4.6.6.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2021); Piesschaert et al. (2022b).

#### 4.6.6.3 Publications

De Knijf et al. (2014); De Knijf et al. (2015); De Knijf et al. (2019b); De Knijf et al. (2021); Westra et al. (2021); De Knijf et al. (2022).

#### 4.6.6.4 References


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Westra T, De Knijf G, Ledegen H, Van de Poel S, Piesschaert F & Onkelinx T. (2021). Resultaten van de Vlaamse libellenmeetnetten voor de periode 2016 - 2020. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2021 (12). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.34106517

### 4.6.7 Grasshoppers

*Geert De Knijf (INBO)*

Two grasshopper species are Flemish Priority Species (Table 15).

Table 15 Grasshoppers monitored in Meetnetten.be. Leg. = Legislation: FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Ephippiger diurnus* | European bushcricket | Zadelsprinkhaan | FPS |
| *Stenobothrus stigmaticus* | Lesser mottled grasshopper | Schavertje | FPS |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of grasshoppers are given in Table 16.

Table 16 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for grasshoppers in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: S = Site count, D = depletion method.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Ephippiger diurnus* | 2016 | I | 5 (4) | 1 | 1 | S |
| *Stenobothrus stigmaticus* | 2017 | I | 2 (3) | 1 | 2 (1) | D |

#### 4.6.7.1 Protocol

De Knijf et al. (2016).

#### 4.6.7.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2022b).

#### 4.6.7.3 Publications

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#### 4.6.7.4 References

De Knijf G, Adriaens T, De Bruyn L, Maes D, Onkelinx T, Piesschaert F, Pollet M, Westra T & Quataert P. (2016). Monitoringsprotocol sprinkhanen. Rapporten van het Instituut voor Natuur- en Bosonderzoek INBO.R.2015.10069987. Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.10069987

Piesschaert F, De Knijf G, Brosens D, Van de Poel S, Westra T, Desmet P & Pollet M (2022a). Meetnetten.be - Sightings for *Ephippiger ephippiger* in Flanders, Belgium. Version 1.2. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/ptdpyx

Piesschaert F, De Knijf G, Brosens D, Van de Poel S, Westra T, Desmet P & Pollet M (2022b). Meetnetten.be - Sightings for *Stenobothrus stigmaticus* in Flanders, Belgium. Version 1.5. Brussels: Research Institute for Nature and Forest (INBO). https://doi.org/10.15468/s8b4x8

European bushcricket (*Ephippiger diurnus*), one of the grasshoppers that is monitored in Meetnetten.be (Picture: Lars Soerink – Vilda).

### 4.6.8 Mammals

#### 4.6.8.1 Bats

*Ralf Gyselings & Luc De Bruyn (INBO)*

Twenty bat species are on the European Habitats Directive seven of which are monitored in Meetnetten.be (Table 17).

Table 17 Bats monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD II: Annex II species of the Habitats Directive).

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Eptesicus serotinus* | Serotine bat | Laatvlieger | EPS (HD IV) |
| *Myotis daubentonii* | Daubenton's bat | Watervleermuis | EPS (HD IV) |
| *Myotis emarginatus* | Geoffroy's bat | Ingekorven vleermuis | EPS (HD II+IV) |
| *Myotis mystacinus* | Whiskered bat | Baardvleermuis | EPS (HD IV) |
| *Myotis nattereri* | Natterer's bat | Franjestaart | EPS (HD IV) |
| *Plecotus auritus* | Brown long-eared bat | Gewone grootoorvleermuis | EPS (HD IV) |
| *Plecotus austriacus* | Grey long-eared bat | Grijze grootoorvleermuis | EPS (HD IV) |
| **Other Habitats Directive species that are not (yet) monitored** | | | |
| *Barbastella barbastellus* | Western barbastelle | Mopsvleermuis | EPS (HD II+IV) |
| *Myotis bechsteinii* | Bechstein's bat | Bechsteins vleermuis | EPS (II+IV) |
| *Myotis brandtii* | Brandt's bat | Brandts vleermuis | EPS (HD IV) |
| *Myotis dasycneme* | Pond bat | Meervleermuis | EPS (HD II+IV) |
| *Myotis myotis* | Greater mouse-eared bat | Vale vleermuis | EPS (HD II+IV) |
| *Nyctalus leisleri* | Leisler’s bat | Bosvleermuis | EPS (HD IV) |
| *Nyctalus noctula* | Common noctule | Rosse vleermuis | EPS (HD IV) |
| *Pipistrellus nathusii* | Nathusius' pipistrelle | Ruige dwergvleermuis | EPS (HD IV) |
| *Pipistrellus pipistrellus* | Common pipistrelle | Gewone dwergvleermuis | EPS (HD IV) |
| *Pipistrellus pygmaeus* | Soprano pipistrelle | Kleine dwergvleermuis | EPS (HD IV) |
| *Rhinolophus ferrumequinum* | Greater horseshoe bat | Grote hoefijzerneus | EPS (HD II+IV) |
| *Rhinolophus hipposideros* | Lesser horseshoe bat | Kleine hoefijzerneus | EPS (HD II+IV) |
| *Vespertilio murinus* | Parti-coloured bat | Tweekleurige vleermuis | EPS (HD IV) |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of bats are given in Table 18.

Table 18 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for bats in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample; #loc/y: number of locations per year; Cycle: 1 = every year; #vis/y = number of visits per year; Meth = method: A = attic counts, W = winter counts.

| **Species** | **stY** | **Type** | **#loc/y** | **Cycle** | **#vis/y** | **Meth** |
|---|---|---|---|---|---|---|
| *Eptesicus serotinus* | 2022 | I | 10 | 1 | 2 | A |
| *Myotis daubentonii* | 2022 | I | 221 | 1 | 1 | W |
| *Myotis emarginatus* | 2022 | I | 9+221 | 1 | 2+1 | A+W |
| *Myotis mystacinus* | 2022 | I | 221 | 1 | 1 | W |
| *Myotis nattereri* | 2022 | I | 221 | 1 | 1 | W |
| *Plecotus auritus* | 2022 | I | 3 | 1 | 2 | A |
| *Plecotus austriacus* | 2022 | I | 3 | 1 | 2 | A |

#### 4.6.8.1.1 Protocol

Onkelinx et al. (2014).

#### 4.6.8.1.2 Datasets

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#### 4.6.8.1.3 Publications

Gyselings et al. (2019).

#### 4.6.8.1.4 References

Gyselings R, Herr C, De Bruyn L & De Knijf G. (2019). Staat van instandhouding (status en trends) van de soorten van de Habitatrichtlijn. Deelrapport vleermuizen (rapportageperiode 2013-2018). Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (19). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.16141531

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#### 4.6.8.2 Non-flying mammals

*Koen Van Den Berge (INBO)*

Three non-flying mammal species are on the European Habitats Directive and one more species is a Flemish Priority Species (Eurasian badger; Table 19).

Table 19 Mammals monitored in Meetnetten.be. Leg. = Legislation: EPS = European Priority Species (HD IV: Annex IV species of the Habitats Directive); FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Cricetus cricetus* | European hamster | Europese hamster | EPS (HD IV) |
| *Lutra lutra* | Eurasian otter | Europese otter | EPS (HD II + IV) |
| *Meles meles* | Eurasian badger | Das | FPS |
| *Muscardinus avellanarius* | Hazel dormouse | Hazelmuis | EPS (HD IV) |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of non-flying mammals are given in Table 20.

Table 20 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for non-flying mammals in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample, UD = Update distribution; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: D = number of dens, N = nest counts, S = spraints, T = traces.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Cricetus cricetus* | 2016 | I | 1 | 1 | 1 | D |
| *Lutra lutra* | 2018 | UD | 5 | - | 1 | S,T |
| *Meles meles* | 2016 | S | 455 | 3 | 1 | D |
| *Muscardinus avellanarius* | 2016 | I | 16 | 1 | 2 | N |

##### 4.6.8.2.1 Protocol

Van Den Berge et al. (2019a).

##### 4.6.8.2.2 Datasets

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##### 4.6.8.2.3 Publications

De Bruyn et al. (2015); Van Den Berge et al. (2019b); Ruyts et al. (2023).

### 4.6.8.2.4 References

De Bruyn L, Van Den Berge K, Verbeylen G, Scheppers T, Gouwy J, Maes D, De Knijf G, Onkelinx T, Piesschaert F, Pollet M, Westra T & Quataert P. (2015). Monitoringsprotocols zoogdieren: Europese hamster, hazelmuis, das, Europese otter. Rapporten van het Instituut voor Natuur- en Bosonderzoek INBO.R.2015.11336560. Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.11336560

Ruyts S, Delief A, Descamps S, Westra T & Van Den Berge K (2023) Hamsters in Vlaanderen - is de soort nog te redden? Zoogdier 34 (2).

Van Den Berge K, De Bruyn L, Verbeylen G, Scheppers T, Gouwy J & Westra T. (2019a). Monitoringsprotocol zoogdieren: Europese hamster, hazelmuis, das en Europese otter - versie 2.0. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (51). Geraardsbergen: Instituut voor Natuur- en Bosonderzoek. http://doi.org/10.21436/inbor.17353371

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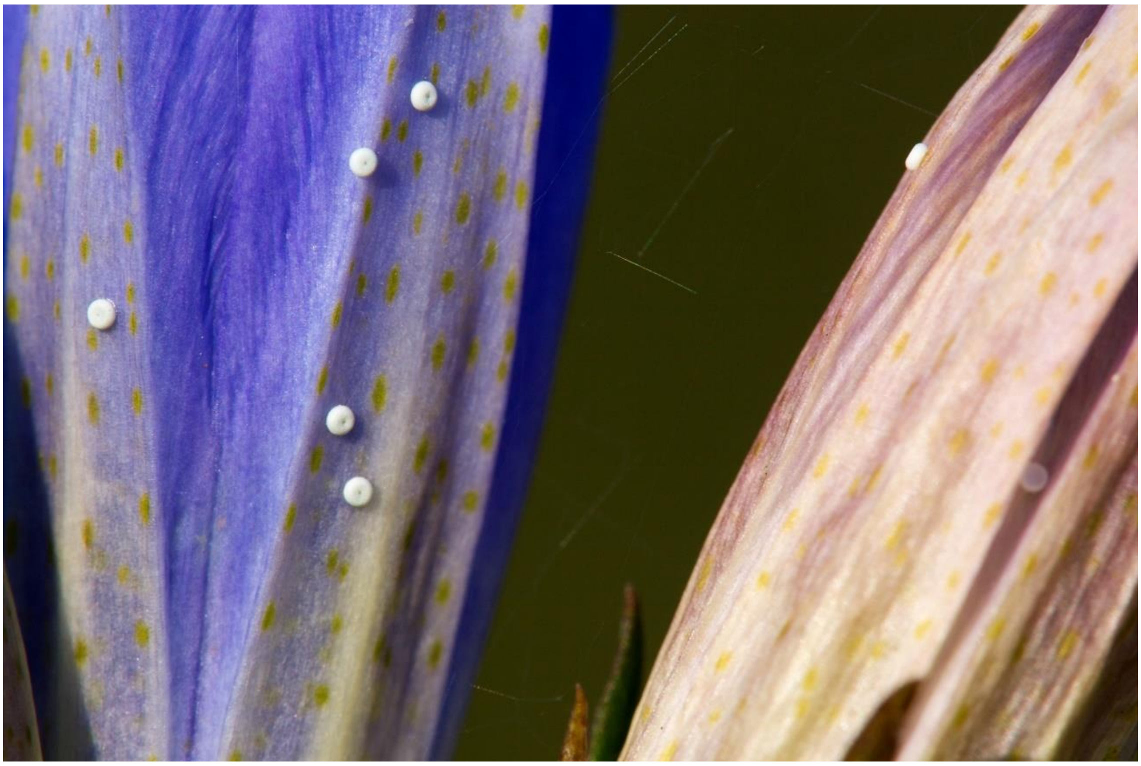

The eggs of the Alcon blue butterfly (*Phengaris alcon*), one of the butterflies that is monitored in Meetnetten.be (Picture: Jeroen Mentens – Vilda).

### 4.6.9 Molluscs

*Jo Packet (INBO)*

Four mollusc species are on the European Habitats Directive (Table 21). Only two of them are present in Flanders. An update of the distribution of these two species is needed before we can start up a monitoring scheme for these species.

Table 21 Molluscs monitored in Meetnetten.be. Leg = Legislation: EPS = European Priority Species (HD II, IV: Annex II, IV species of the Habitats Directive); FPS = Flemish Priority Species. † = Extinct.

| Species | English name | Dutch name | Leg |
|---|---|---|---|
| *Anisus vorticulus*† | Little whirlpool ramshorn snail | Platte schijfhoren | EPS (HD II+IV) |
| *Vertigo angustior* | Narrow-mouthed whorl snail | Nauwe korfslak | EPS (HD II) |
| *Vertigo moulinsiana* | Desmoulin's Whorl-snail | Zeggekorfslak | EPS (HD II) |
| *Unio crassus*† | Thick shelled river mussel | Bataafse stroommossel | EPS (HD II) |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of molluscs are given in Table 22.

Table 22 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for molluscs in Meetnetten.be. stY = starting year; Type: UD = Update distribution; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: G: searching on stems, S = sieving, T = transects, W = water samples.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Vertigo angustior* | 2017 | UD | - | - | - | S |
| *Vertigo moulinsiana* | 2017 | UD | 15 | 1 | 1 | G |

#### 4.6.9.1 Protocol

Packet et al. (2018).

#### 4.6.9.2 Datasets

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### 4.6.9.3 Publications

De Knijf et al. (2019).

### 4.6.9.4 References


De Knijf G, Maes D, Packet J & Thomaes A. (2019). Staat van instandhouding (status en trends) van de soorten van de Habitatrichtlijn. Deelrapport insecten en mollusken (rapportageperiode 2013-2018). Rapporten van het Instituut voor Natuur- en Bosonderzoek 2019 (8). Brussel: Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.16089417

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Narrow-mouthed whorl snail (*Vertigo angustior*), one of the molluscs that is monitored in Meetnetten.be (Picture: Jeroen Mentens – Vilda).

### 4.6.10 Spiders

*Koen Van Keer (ARABEL)*

Two spider species are Flemish Priority Species (Table 23).

Table 23 Spiders monitored in Meetnetten.be. Leg. = Legislation: FPS = Flemish Priority Species.

| Species | English name | Dutch name | Leg. |
|---|---|---|---|
| *Dolomedes fimbriatus* | Raft spider | Gerande oeverspin | FPS |
| *Eresus sandaliatus* | Ladybird spider | Lentevuurspin | FPS |

The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for the monitoring of spiders are given in Table 24.

Table 24 The starting year, the type of monitoring, the number of locations, the yearly cycle, the number of visits per year and the methods for spiders in Meetnetten.be. stY = starting year; Type: I = integral, S = subsample, UD = Update distribution; #loc/y: number of locations per year; Cycle: 1 = every year, 3 = 3-year cycle; #vis/y = number of visits per year; Meth = method: S = Site count, W = counting webs.

| Species | stY | Type | #loc/y | Cycle | #vis/y | Meth |
|---|---|---|---|---|---|---|
| *Dolomedes fimbriatus* | 2016 | UD | 10 | 6 | 10 | S |
| *Eresus sandaliatus* | 2016 | I | 3 (4) | 1 | 1 | W |

#### 4.6.10.1 Protocol

Van Keer et al. (2020).

#### 4.6.10.2 Datasets

Piesschaert et al. (2022a); Piesschaert et al. (2022b).

#### 4.6.10.3 Publications

Van Keer et al. (2011); Van Keer et al. (2015); De Witte et al. (2023); Van Keer (2023).

#### 4.6.10.4 References

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Ladybird spider (*Eresus sandaliatus*), one of the spiders that is monitored in Meetnetten.be (Picture: Rollin Verlinde – Vilda).

# 5 Discussion

An evaluation of international and regional conventions and legislations regarding species of conservation concern, revealed that 85 species with monitoring obligations were not covered by any established monitoring scheme in Flanders until 2015. By adapting established monitoring schemes and the development of the new Meetnetten.be monitoring schemes, we managed to launch monitoring schemes for 63 species and to start the preparation of such schemes for another nine species. The targeted design of the Meetnetten.be monitoring schemes approach in Flanders will enable researchers to detect trends more reliably than with opportunistic observations only. It will also allow policy makers to select species for which conservation management measures are most urgent (Román-Palacios & Wiens 2020).

The vast majority of the species of conservation concern in Flanders is monitored through a close collaboration between a governmental institute (i.e., the Research Institute for Nature and Forest – INBO), a governmental agency (Agency for Nature and Forests, ANB) and citizen scientists co-ordinated by the largest nature NGO in Flanders (i.e., Natuurpunt). Only fish species (EU Habitats Directive, EU Eel Regulation), some plants (EU Habitats Directive) and Grey wolf (EU Habitats Directive) are (largely) monitored by government employed scientists for various reasons (historical obligations, monitoring intricacy, etc.). The new monitoring schemes were especially designed to be carried out by citizen scientists because monitoring conducted solely by professional scientists is too expensive and, therefore, not feasible on a large scale and long term (Chandler et al. 2017; MacPhail & Colla 2020). Besides providing benefits of scale and cost-effectiveness (e.g., Gardiner et al. 2012), verified citizen science is also an established methodology that provides learning outcomes, increases environmental awareness and fulfilment with citizen scientists (Jordan et al. 2011; Roy et al. 2012).

## 5.1 IMPROVED QUALITY AND USABILITY OF OPPORTUNISTIC MONITORING DATA

Opportunistic data collected by trained citizen scientists are challenging to analyse and recently innovative hierarchical models for trend calculations accounting for possible biases in the observation process are being developed (e.g., Fajgenblat 2019). An example of such models is Site Occupancy Modelling (Kéry et al. 2010), as already applied for several species in the Netherlands and even on supranational levels (e.g., van Strien et al. 2013). To increase the statistical power of these models, citizen scientists are asked to provide information on all species of a certain taxonomic group present in a site (the 'full species list principle') so that absences can be imputed more reliably (Isaac et al. 2014; Van Eupen et al. 2021; Van Eupen et al. 2022). Improving the way citizen scientists collect data in the field will be promoted by improved mobile applications and new techniques. These innovative applications for Waarnemingen.be will also involve a broader part of society and match the skill-level of each person to the type of data he/she gathers. Another application of opportunistic observations is combining them with structured data (long-term monitoring data collected by professional scientists) to increase the precision of estimated population trends (Kamp et al. 2016; Sumner et al. 2019). The data in Waarnemingen.be are validated either automatically or by experts, based on phenology, known distribution of the species, associated photos (e.g., Vantieghem et al. 2017) and observer expertise which guarantees a good level of data accuracy (Vanreusel et al. 2018).

## 5.2 THE FUTURE OF MONITORING IN FLANDERS

### 5.2.1 Dovetailing monitoring schemes and databases across regions and stakeholders

Many international or regional conventions oblige or recommend the monitoring of species and/or habitats to estimate their status, but they do not mention how this monitoring should be carried out, leading to a vast array of approaches in different regions (Ellwanger et al. 2018). Dovetailing monitoring schemes across regions would make trend estimations much more comparable and would facilitate the reporting of the state of species and/or habitats on different geographical levels (e.g., currently one region reports trends in distribution while others report on changes in abundance). Within Flanders, a few species are monitored by different schemes (e.g., Eurasian badger *Meles meles* in the Marten Network and in Meetnetten.be, Gatekeeper *Pyronia tithonus* in the Flemish Butterfly Monitoring Scheme and in Meetnetten.be). This is mainly due to differing goals in the respective monitoring schemes: Meetnetten.be focuses on one particular species, while the Flemish Butterfly Monitoring Scheme and the Marten Network gather information about species communities. Monitoring data are mostly stored in different databases managed by the most appropriate specialists of the different coordinating bodies or stakeholders (e.g., hunters, anglers) but could be made accessible in one overarching web portal. Access to biodiversity data for both the public and the scientific community (Hoffmann et al. 2013) can be improved by publishing the data in a standardised format using an Open Access repository (e.g., GBIF – Robertson et al. 2014). This is of key importance to its applicability. Moreover, the availability of opportunistic data via this kind of public portals might provide extra recognition for citizen science contributions (Groom et al. 2017). For this reason, at present monitoring data produced by the Meetnetten.be schemes are systematically published as datasets on GBIF (filter on 'Meetnetten.be' data sets in https://ipt.inbo.be). Having these data from different regions and countries available in an open and uniform data format could strongly facilitate data flows for trend calculations on supranational level.

### 5.2.2 New techniques for improving monitoring schemes and the involvement of citizen scientists

Some species are very difficult to distinguish from sibling species (e.g., Common frog (*Rana temporaria*) versus Moor frog (*Rana arvalis*) – Brys et al. 2020), while others are very rare (European wheatherfish (*Misgurnus fossilis*) – Van Wichelen et al. 2020) or illusive (Eurasian otter (*Lutra lutra*) - Van Milders et al. 2023), making them difficult to monitor. To include these species in monitoring schemes, new methods are developed and explored. Environmental DNA (eDNA) is currently being explored, in particular for aquatic species and communities and, if successful, might be applied in our monitoring schemes in the near future.

If gathering information on multispecies communities is the aim, and in particular if expertise for identification is limited, then metabarcoding seems a promising way forward. For this purpose, all the DNA present in a sample is used and compared with that in a worldwide library (e.g., GenBank, BOLD Systems) in which DNA sequences of a large number of species are stored. These open access DNA repositories are constantly extended with new species and sequences. This also allows sequences from unidentified species to be named. Comparing samples with an unknown species composition to a DNA reference database is called metabarcoding (Hebert et al. 2003; Ji et al. 2013; Liu et al. 2020; Svenningsen et al. 2021; Swenson et al. 2022; Iwaszkiewicz-Eggebrecht et al. 2023). Here, we are not looking for one specific species, but for the entire species composition and/or richness in a sample. In Flanders, the use of metabarcoding for surveying and monitoring wild bees and other pollinators s currently considered. Indeed, butterflies, wild bees, hoverflies and moths together number more than 1300 species and are often caught in large numbers in pan traps or Malaise traps and large scale monitoring schemes will inevitably produce huge amounts of samples. In Flanders, however, only a handful of specialists are present to identify the species (Hochkirch et al. 2022). Research into soil organisms such as earthworms, centipedes, springtails and other invertebrates such as dead-wood beetles would also greatly benefit from metabarcoding or even eDNA sampling (see further), since these species groups are species-rich or very hard to separate from each other and hardly studied in Flanders. AirDNA captures environmental DNA from air. Although it is still in its infancy, it could allow straightforward collection and characterization of terrestrial (vertebrate) communities. Shorter distances of animals to the air sampling device and higher animal biomass increase the probability of detection. Airborne eDNA can offer a fundamentally new way of studying and monitoring terrestrial communities (Garrett et al. 2022; Lynggaard et al. 2022).

The introduction of other new methods presents additional challenges. One example is monitoring of bats. Most of the bat species are now only monitored in their hibernating sites, at species complex level, and only rarely in their summer biotopes. Automatic monitoring using bat detectors (e.g., Stahlschmidt & Bruhl 2012; Brabant et al. 2018; Krivek et al. in press) could result in large scale recording of occurrence data of these nocturnal species during their activity season. However, this easily results in many thousands of recordings that need to be annotated. Although automatic species identification software has been developed and is improving, validation by experts remains necessary.

For species that are hard to detect because of their illusive behaviour, insufficiently known natural history or extreme rarity (e.g., Hermit beetle, *Osmoderma ermita*), conservation dogs have been trained to detect their presence by smell (Bennett et al. 2020; Grimm-Seyfarth et al. 2021). In Flanders, this has been applied successfully to the Eurasian otter (*Lutra lutra*), the Stag beetle (*Lucanus cervus* – Thomaes et al. 2016) and the Grey wolf (*Canis lupus* - Vervaecke et al. 2021) but proved unsuccessful for hibernation nests occupied by Hazel dormice (*Muscardinus avellanarius* – Verbeylen et al. 2017). The dog was able to detect shrub nests during the active season though, but the citizen scientists were able to find more nests than the dog did (e.g., older nests that had lost their smell). For the latter species, forensic swabs could be used as an alternative (Priestley et al. 2021). In the years to come, more conservation dogs will be trained to detect species of conservation concern. Involving conservation dogs might lead to a faster detection of certain focal species, but definitely comes at a cost and long-term investments (incl. training, feeding and accommodation of dogs).

### 5.2.3 Drawbacks and opportunities for citizen scientists

#### 5.2.3.1 Drawbacks

Not all new monitoring approaches, however, are equally applicable by or attractive for citizen scientists. Also, novel technologies for citizen science have different value with respect to gathering new information, improving data quality (or not) and increasing inclusivity, engagement and participation (e.g., August et al. 2015). Some methods might even cause reluctance among citizen scientists to collaborate, especially if it entails sampling or killing of animals (e.g., Moor frog *Rana arvalis* and Pool frog *Pelophylax lessonae*). Currently, Moor frog monitoring in Flanders is done by combining the collection of a representative number of eggs, egg clutch counting in the field and the (destructive) identification of the eggs by molecular methods. This should allow us to calculate ratios of reproduction between Moor frog and Common frog (*Rana temporaria*) which often oviposit in the same water bodies. On the other hand, Pool frog monitoring is done by estimating populations via counting calling males and calculating ratios among other *Rana* species on the basis of their proportion in the larval community using molecular identification (based on cut parts of the larval tails). Both monitoring schemes are conducted by professional researchers but citizen scientists are encouraged to collaborate with the field work.

Recently developed applications for sound recognition are used for registering calling frogs (e.g., FrogPhone – Garrido Sanchis et al. 2020; RIBBIT - Lapp et al. 2021) or bird sounds (Potamitis et al. 2014). Other automated monitoring equipment (networks of camera traps) is being developed for nocturnal insects (Ruczyński et al. 2020) and mammals (Steenweg et al. 2017). Some of these novel techniques are too expensive for citizen scientists or are challenging in terms of data mobilisation and management and might, therefore, mostly need substantial resources (most presumably by the government).

#### 5.2.3.2 Opportunities

New techniques and/or approaches to monitor species not necessarily render traditional field work or citizen science obsolete. Indeed, citizen scientists can, for example, collect eDNA samples successfully with only limited training which could greatly increase the scale of surveys and can overcome data constraints (Biggs et al. 2015). Of course, as the mere observation of the focal species is often the main reward and motivation for the citizen scientist, to be involved in long term monitoring, eDNA sampling might entail another way of coaching or motivating these field workers. Citizen scientists will also be involved in the monitoring of illusive beetle species by using sexual pheromones. These pheromones attract individuals and can be used to estimate their presence and abundance (Larsson 2016). In Flanders, the application of this technique has recently been successfully tested for the Rusty click beetle (*Elater ferrugineus* - Thomaes et al. 2019) and will be rolled out in the next monitoring cycle.

As explained in the previous chapters, long-term monitoring of priority species requires substantial resources over long periods of time. For each species a specific monitoring scheme must be designed, and a monitor protocol developed, tested and executed at a large scale in order to calculate reliable population trends for the whole of Flanders. It is obvious that the scientific basis for this approach strongly relies on the knowledge of professional (taxonomic) experts, including the development of the scheme and protocol, as well as the ultimate analysis and reporting. In most cases, however, its execution cannot be done without the involvement of citizen scientists and their organisations. In Flanders, next to the field work the latter are also responsible for the conversion of the protocols into practical field manuals, the training of new recruits and the follow-up of the field work. While the extant protocols are systematically improved on the basis of feedback by the citizen scientists, researchers explore and develop novel methods that might be more cost-effective and cost-efficient. But at least for widespread and reasonably easily encountered and recognised species or species with wide distribution ranges, citizen scientists will always remain a key success factor (Van Eupen et al. 2022). Furthermore, the increasingly available technologies on smartphones such as ObsIdentify for image recognition (Schermer & Hogeweg 2018) and BirdNET (Kahl et al. 2021) or Merlin (Van Horn et al. 2015) for audio recognition of bird songs (Wood et al. 2022; Pérez-Granados 2023), driven by powerful artificial intelligence and deep learning algorithms are promising tools to involve a broader range of citizen scientists in environmental monitoring or to develop automated monitoring tools.

### 5.2.4 Dedicated monitoring schemes for invasive species

The monitoring of Union List Invasive Alien Species (IAS), a requirement of the EU Regulation 1143/2014, is currently heavily reliant on opportunistic data from the citizen science platform Waarnemingen.be (Adriaens et al. 2018). It represents a primary source of occurrence data of Union List IAS and an important complement to the professional monitoring schemes. The alien species data from this platform are entirely (and at the highest spatial resolution) published on GBIF (Swinnen et al. 2018). This dataflow feeds research pipelines in support of decision making on IAS (risk assessment, risk management), and also the Belgian early alert system (https://alert.riparias.be) which informs managers on new occurrences of target species. To fulfil the monitoring and reporting obligations for species of European Union Concern, data from existing monitoring schemes are used. For birds and mammals, these are the Waterbird Counts (IAS: Egyptian goose, Ruddy duck), the Common Birds Census (Egyptian goose), the Rare Birds Census (Ruddy duck) and the Marten Network (Raccoon, Common raccoon dog). For casual and established plant species from the list (*Ailanthus altissima, Asclepias syriaca, Baccharis halimifolia, Cabomba caroliniana, Eichhornia crassipes, Elodea nuttallii, Heracleum mantegazzianum, Hydrocotyle ranunculoides, Impatiens glandulifera, Lagarosiphon major, Ludwigia grandiflora, Ludwigia peploides, Lysichiton americanus, Myriophyllum aquaticum, Myriophyllum heterophyllum, Parthenium hysterophorus* and *Salvinia molesta*), data from Florabank are used. For fish, crayfish and Chinese mitten crab the fish monitoring scheme yields useful data. For Asian hornet, there is a dedicated citizen science programme (www.vespawatch.be). A monitoring network for invasive crayfish is in preparation and will strongly rely on eDNA. Environmental DNA is also used for detection of American bullfrog. Semi-structured monitoring is also performed for Chinese muntjac using camera traps linked to the wildlife camera trapping Agouti platform in a few high risk areas. The geographic scope of this surveillance is planned to be extended. With the exception of carnivores from the Marten Network, all datasets from existing monitoring schemes containing records of Union List species are published on GBIF. There are plans to also do this for monitoring/research data from projects that use the Agouti platform. These data from structured monitoring, opportunistic and structured citizen science are supplemented with data from various management actors in the region that manage IAS and often have their own tools (smartphone apps, GIS systems) for data reporting. Here, a dedicated effort is being undertaken to standardise reporting on management and to openly publish these data. To implement structured surveillance schemes for IAS would, however, require a similar conceptual approach to the set-up of Meetnetten.be, considering monitoring requirements, survey design (e.g., areas at risk of introduction and/or points of entry, areas at risk of impact), current data availability and a governance framework (cf. 4.4). A first step would involve using the systematic approach of Onkelinx et al. (2008) to determine information needs and plan for data collection and analysis.

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