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I-SWAMP

Output 1.1: Guidelines

for biodiversity monitoring and conservation of small Alpine wetlands

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1. Small Alpine Wetlands

1.1 Introduction

1.1.1 Why do we need these guidelines?

These guidelines are designed to provide basic guidance for biodiversity monitoring and conservation of **small wetlands in the Alpine region**. Wetlands constitute a category of **ecosystems** characterised by the **regular or permanent presence of water** (Keddy, 2010). These environments include ponds and shallow lakes, peatlands, marshes, wet meadows, swamps (Keddy, 2010), representing an important part of the Alpine environment and its diverse ecosystem biodiversity. They host many **characteristic or protected species**, include **habitats of community interest**, and provide essential **ecosystem values and services** to our communities, ranging from carbon storage to water supply, from flood risk reduction to clean water.

Wetlands face challenges globally, with their total surface estimated to have decreased by over 50% in recent centuries (Davidson, 2014). Even in the Alpine environment, though relatively more preserved compared to neighbouring regions, significant changes in land use and management, including management of wetlands, have occurred due to major socio-economic shifts in the last century (Bonometto, 2020). This has resulted in the **loss of numerous important sites**, a loss that is currently challenging to estimate or evaluate (e.g., see Bonometto, 2020).

Simultaneously, wetlands are among the most **underestimated and often disregarded** environments by local communities, traditionally viewed as hazardous, unhealthy, or unproductive (this is reflected in expressions across several European languages). Their biodiversity and value remain relatively unknown to the general public.

The I-SWAMP project is dedicated to the **integrated conservation** of these environments, focusing on smaller, typically less known, less protected, more easily damaged sites, yet also more straightforward to protect and restore. We selected several sites in Austria, Italy, and Slovenia, monitoring and implementing small restoration interventions (such as pond restoration, tree and shrub removal, mowing, and fencing, etc.). Local communities and schools were actively involved in these activities.

While **pilot interventions are crucial**, it is evident to us that their realisation alone is insufficient, given the numerous sites in need of protection or restoration. **Small administrations**, landowners, and associations involved in the maintenance of natural environments **often lack the expertise or personnel** for these interventions. Therefore, we present these **guidelines** for the monitoring and conservation of small Alpine wetland areas, especially **dedicated to these stakeholders**.

1.1.2 The structure and the scope of these guidelines

You will find **three main sections** in these guidelines. The **first**, in this chapter, briefly introduces the **types of wetlands** present in the Alpine region, and provides general guidance on how to recognise them. The **second**, in Chapter 2, provides instructions on **monitoring several important groups** (vegetation, amphibians, dragonflies, butterflies), all including several rare, protected, or flagship species. This monitoring can offer insights into the state of wetlands because effective conservation interventions require a thorough understanding of the biodiversity in the considered environments. This knowledge ensures that interventions are decided and adapted based on habitat potential and to avoid harm to species or habitats of interest.
The **third** part, in Chapter 3, presents a series of **conservation or restoration** proposals categorised by wetland type and addressing some of the primary pressures each category faces. For each pressure, a diagnostic section ("**What to expect?**"), an intervention proposal section ("**What to do?**"), and a section highlighting potential issues with suggested solutions ("**Problems**") are provided.

Please note that **these guidelines are designed only for small wetlands where the primary pressures are easily identifiable and where there are no severe problems requiring complex interventions**. Use them for smaller environments (less than 2 hectares) within the Alpine environment. If your wetlands are within or nearby Natura 2000 sites or other protected or relevant areas, if the sites host species of community interest or other species protected under other regional or national laws or regulations, if the sites are particularly extensive and important, or if issues are not easily recognisable and require significant works, seek assistance from external experts in ecology and/or environmental engineering. Note that **an expert in biodiversity and conservation of wetlands should always be present when planning and implementing wetland monitoring and conservation**. **Always follow the laws, regulations or guidelines available** at the regional or national level. In any case, try to avoid highly invasive interventions on large surfaces unless recommended or approved by experts and required or authorized by regional or national authorities. Aim to **maintain a certain management diversity** to foster a heterogeneous landscape with diverse environments under different conditions, promoting greater species and habitat diversity.

1.1.3 Definition of wetlands

"*A wetland in an ecosystem that arises when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding*" (Keddy, 2010). This complex definition introduces the **primary factor** determining the formation of wetlands (the **regular or permanent** presence of water, with **flooded or waterlogged soils**), the initial **consequence** of this condition, relatively rare in terrestrial environments (the presence of **anaerobic soils**), and the observable **effect on the community** (the presence of rooted **plants exhibiting adaptations to life in flooded soils**) (Keddy, 2010, Schumann & Joosten, 2008). Usually, lakes (except shallow lakes) and watercourses are not classified as wetlands but are treated separately

(Keddy, 2010). Nevertheless, in nature, **there is often no clear boundary** between these environments and wetlands, nor between different types of wetlands (Keddy, 2010).

1.1.4 Wetland types in the Alps

All wetlands found worldwide can be assigned (at least in some parts) to one of six categories (Keddy, 2010). Interestingly, in the Alpine environment, all these categories are present, and are described in detail below. A more detailed description can be found in chapter 3.

1.1.4.1 Swamps

Swamps are environments **dominated by tree species**, often, in the Alpine environment, including species in genera such as *Alnus*, *Fraxinus*, *Salix*, and others (see **Figure 1.1**) (Aeschimann et al., 2011; Keddy, 2010). These environments are typically flooded for short periods each year and are often located in valley bottoms near watercourses (Keddy, 2010).

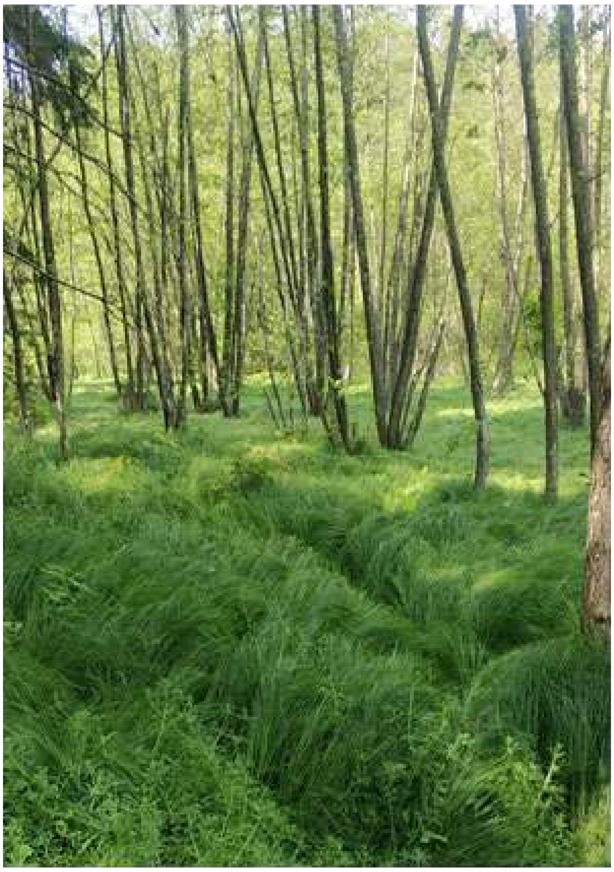

Figure 1.1: Alder (*Alnus* sp.) wood along slow river (Prevalje, Slovenia, photo: B. Trčak)

1.1.4.2 Wet meadows

Wet meadows are open environments **dominated by herbaceous vegetation**, typically flooded very infrequently (Keddy, 2010). Examples in the Alpine region include *Molinia* meadows and tall herb fringes (see **Figure 1.2**).

Figure 1.2: A tall herb fringe wet meadow dominated by herbaceous vegetation such as *Filipendula ulmaria* (San Vito di Cadore, Italy, photo: G. Menegus)

1.1.4.3 Marshes

Marshes are wetlands dominated by **herbaceous species rooted and emergent through water** (Keddy, 2010). These environments often host monospecific stands of dominant species (*Phragmites*, *Typha*, *Carex* etc., see **Figure 1.3**) in areas that are frequently flooded, typically near other wetlands or bodies of water (Aeschimann et al., 2011; Keddy, 2010).

Figure 1.3: A marsh dominated by *Carex elata* (Gallizien, Austria, photo: G. Menegus)

1.1.4.4 Peatlands: fens

Fens are peatlands **dominated by herbaceous plants**, often sedges (*Carex* sp. and other *Cyperaceae* see **Figure 1.4**), and certain genera of mosses (e.g., *Scorpidium*, *Drepanocladus*) (Keddy, 2010); they are a type of peatland mostly fed by groundwater or discharge water and exhibit a thin layer of peat, in addition to having a pH higher than 6 (Keddy, 2010).

Figure 1.4: A fen dominated by *Eriophorum latifolium* (in the photo) and *Menyanthes trifoliata* (Lozzo di Cadore, Italy, photo: G. Menegus)

1.1.4.5 Peatlands: bogs

Bogs are peatlands **dominated by mosses of the genus *Sphagnum*,** which often form structures with **hummocks and hollows** (see **Figure 1.5**)(Keddy, 2010; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). These environments are characterized by a deep layer of peat, where the upper part of the soil is exclusively fed by precipitation water, and the pH is generally very low (Keddy, 2010; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019).

1.1.4.6 Shallow water bodies

Shallow water bodies, including **ponds and shallow lakes**, are **aquatic habitats** that can be permanent or temporary, typically with a water level above 25 cm (see **Figure 1.6**), and are dominated by aquatic plants (Keddy, 2010).

Figure 1.5: Bogs tend to be dominated by *Sphagnum* mosses, thriving on poor acidic soils, often displaying a structure of hummocks and hollows (Lozzo di Cadore, Italy, photo: G. Menegus)

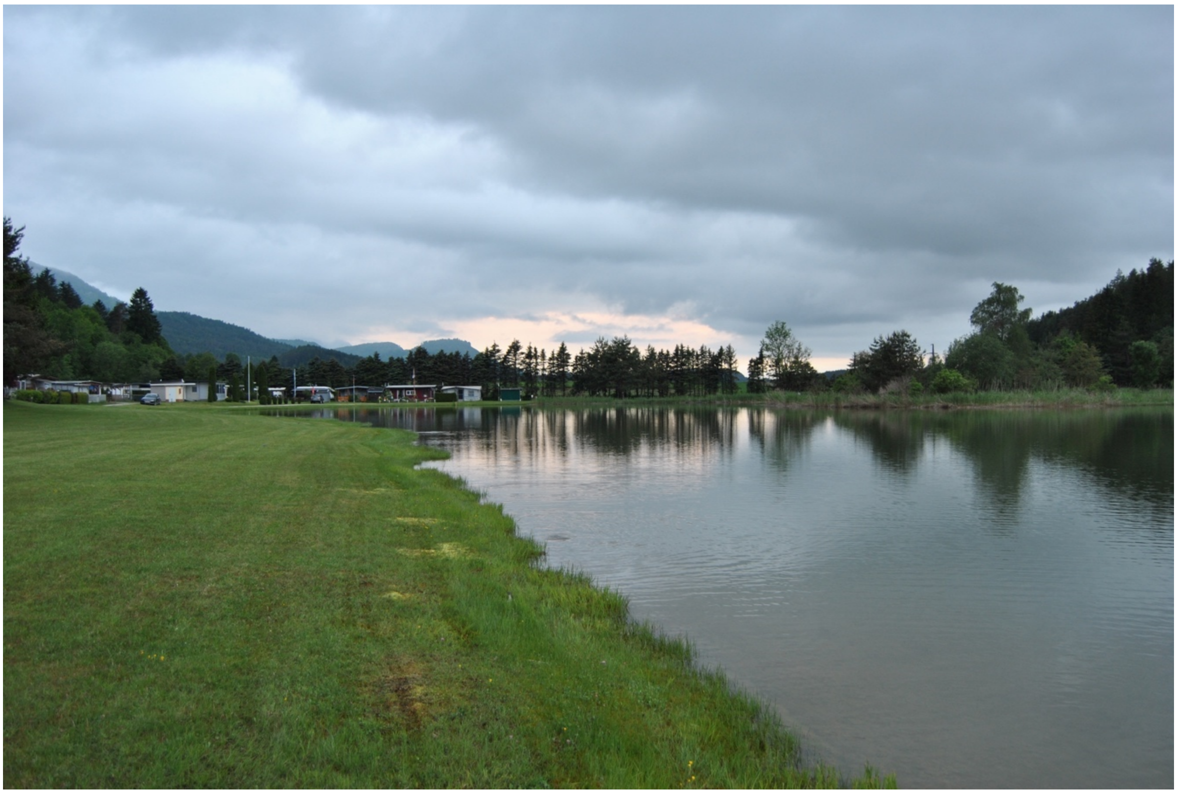

Figure 1.6: A shallow lake with a strip of hydrophilic vegetation: ponds and shallow lakes, either permanent or temporary, are considered wetlands (Feistritz ob Bleiburg, Austria, photo: G. Menegus)

2. Biodiversity monitoring

2.1 Introduction

Regarding biodiversity monitoring, in these guidelines, we propose focusing on four groups (**vegetation, amphibians, dragonflies, butterflies**). All these groups are **characteristic** of wetlands, relatively **easy to study**, and the necessary taxonomic skills are relatively widespread among naturalists and ecologists. This does not imply that they represent the most important groups or the best for understanding the conservation status of Alpine wetlands, but in the case of small sites, available **resources may not be sufficient to study other groups** (**macrobenthos**, including water beetles, hemipterans, and larvae of dipterans, crustaceans, oligochaetes, molluscans, or terrestrial beetles, **algae**, **birds**, **fish**, etc.). **Rely on an expert** to assess whether it is necessary to include different groups in your case or if reducing your work to a couple of groups may be sufficient. However, we recommend studying **at least vegetation and at least one group of animals.**

2.2 Vegetation

2.2.1 Introduction

Monitoring serves the purpose of documenting change. Typically, biodiversity monitoring is carried out to identify, record, and analyse the impacts of a change process on a natural system. It is irrelevant whether the change is a result of human interaction or natural processes. **Vegetation monitoring** involves assessing parameters such as the presence of specific **plant species**, the **species composition** of plant communities, or the **abundance** of plant species or communities in a designated area. By correlating changes in these parameters with implemented measures, their effectiveness can be documented and analysed.

2.2.2 Minimal requirements of the survey

Vegetation assessments should be conducted by a **vegetation expert**, particularly in the case of wetlands, where **expertise in moss species is highly recommended**. At a minimum, **familiarity with typical wetland habitats is essential**, along with **knowledge of vascular plant species** and the correct procedures for their proper collection and expert determination. The optimal time for assessing plants (and plant communities) is during the vegetation period, typically **from May until September** (depending on the vegetation type and altitude), when most vascular plants can be identified at their optimum development stage.

A list of wetland **habitat types of community interest** as per the **92/43/CEE** “**Habitats” Directive**, is provided in the following table.

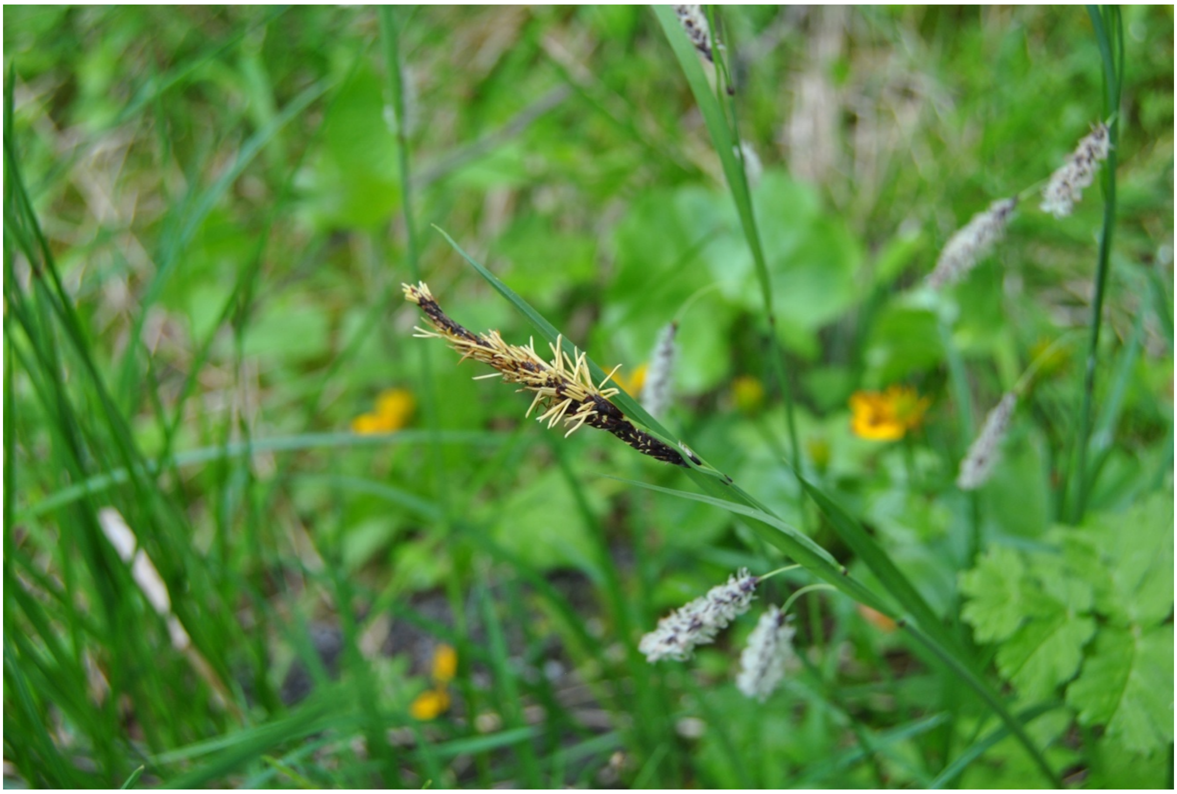

Figure 2.1: sedges (*Cyperaceae*), such as *Carex flacca*, are common in wetlands (photo: G. Menegus)

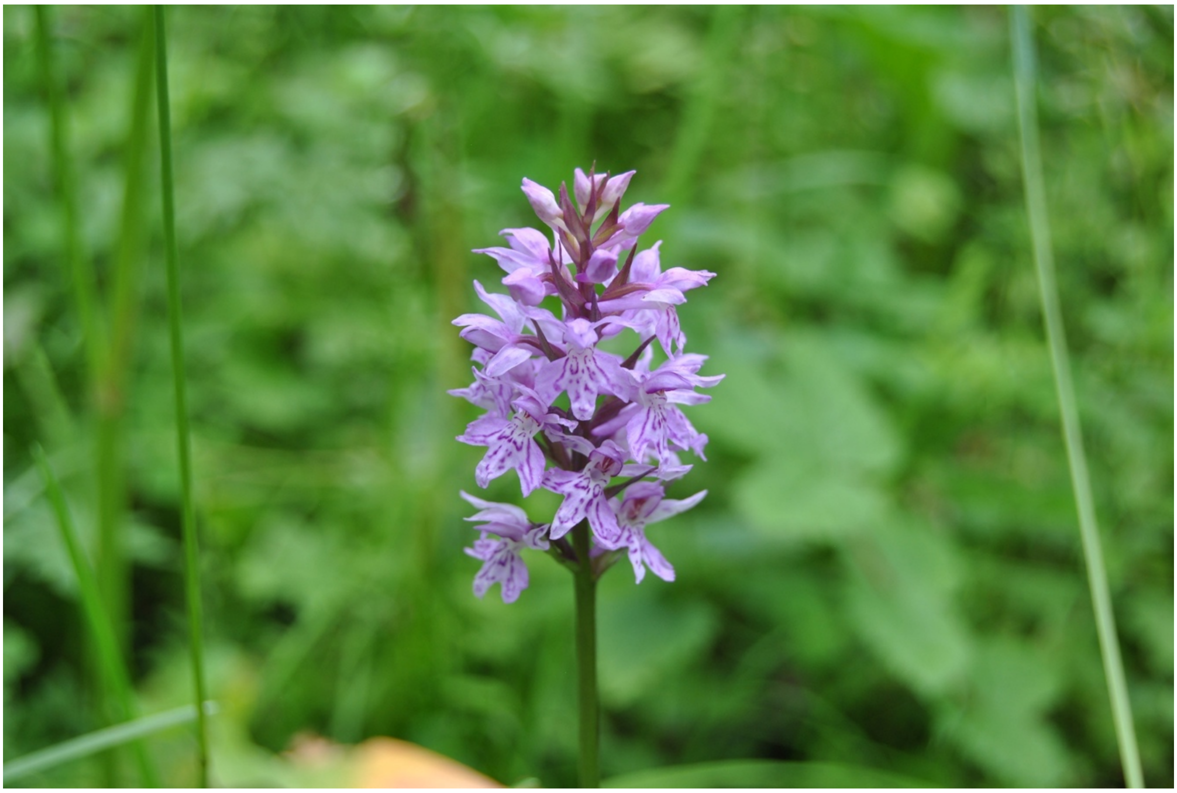

Figure 2.2: Orchids (*Orchidaceae*), such as *Dactylorhiza maculata* subsp. *fuchsii* are well-adapted to life in saturated soils (photo: G. Menegus)

Table: List of wetland or wetland-related habitats types deemed of community interest (Annex I, 92/43/CEE "Habitats" Directive)

FFH-Code	Habitat Type according to EU Legislation
3130	Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoëto-Nanojuncetea*
3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation
3160	Natural dystrophic lakes and ponds
6410	Molinia meadows on calcareous, peaty or clayey-silt- laden soils (*Molinion caeruleae*)
6420	Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6510	Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)
6520	Mountain hay meadows
7110	* Active raised bogs
7120	Degraded raised bogs still capable of natural regeneration
7140	Transition mires and quaking bogs
7210	*Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
7220	* Petrifying springs with tufa formation (*Cratoneurion*)
7230	Alkaline fens
7240	* Alpine pioneer formations of *Caricion bicoloris-atrofuscae*
91D0	* Bog woodland
91E0	* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)

Additionally, there are **other types to be considered**, which may not fall under EU legislation but are nonetheless crucial habitats, such as acidic fens, wet meadows, bushland dominated by willow or ash, forest mires, small ponds, reeds and sedge beds, etc.

2.2.3 Suggested protocol

This protocol builds on the phytosociological relevé method (Braun-Blanquet, 1964).

1. **Gather information** from previous surveys, scientific literature, and local knowledge. Previous surveys may provide data on habitat types and a list of plants.

2. Prepare a **selection of expected plant species** found in wetland habitats. Knowledge about common genera in wetland habitats, such as *Carex*, *Juncus*, etc., is a minimum requirement.

3. **Check if you need permissions or a license** for the surveys. This includes permission to collect data on-site, whether on private or public property. In protected areas, specific regulations may apply to trespassing. Additionally, permissions may be necessary for collecting plants or plant parts, even outside protected areas, especially if they are legally protected (when they are needed for determination purposes or to establish an herbarium). Simple and non-invasive survey methods can usually be conducted without permissions and are preferable for involving citizen scientists or amateurs in monitoring.

4. **Determine the optimal time** for the survey. In lower altitudes, the first half of the vegetation season (**May to July**) may be ideal, while in higher elevations, **mid-July to August** might be suitable. Plants should be fully developed, displaying blossoms and, ideally, seeds, for reliable species determination.

5. **Identify representative areas** within the wetland with homogenous vegetation. Establish at least one plot of 3 x 3 m^2 for each habitat type (see **Figure 2.3**). To facilitate future surveys, mark at least two corners with a piece of metal (e.g., a magnet or marking nail) and record GPS coordinates of the corner points. Assessing the distance and angle to permanent structures nearby can aid in retrieval. Accuracy is crucial.

Figure 2.3: A vegetation ecologist sampling a 3x3 m vegetation plot (Sittersdorf, Austria)

6. **Assess site characteristics**, including elevation, inclination, cardinal direction, coverage with bushes or plants indicating disturbance (e.g., invasive species). Record general information about hydrology, disturbances, land use, threats, recommendations for maintenance, etc.

7. **Assess all plant species and estimate their cover** using the Braun-Blanquet scale (1964). Evaluate vegetation in separate layers (trees > 5 m, shrubs 1-5 m,

herbal layer 0-1 m, and moss layer). Collect individuals of unclear moss species for further determination by a moss expert.

8. After plot assessment, **evaluate additional plant species** within the habitat.

9. **Repeat the process** for other homogeneous areas in neighbouring habitats.

10. **Visit nearby sites**, too.

2.3 Amphibians

2.3.1 Introduction

Most **amphibians** exhibit a **terrestrial phase**, spending the majority of the year on land, and an **aquatic phase**, during which they gather, often in large numbers, for **breeding in ponds or other water bodies** (see **Figure 2.4**) (Speybroeck et al., 2018). The hatchlings then spend the initial part of their lives as **larvae or tadpoles**. While there are exceptions to this pattern (e.g., *Salamandra atra*), this intricate life history makes amphibians **valuable indicators for assessing the quality of wetlands** (Speybroeck et al., 2018). Their presence indicates that both aquatic and terrestrial habitats are suitable for sustaining the life of the amphibian species present (Speybroeck et al., 2018). Moreover, amphibians serve as an **excellent flagship group**, being appreciated and sometimes well-known by the general public. Additionally, some species are protected in the Alpine region and are listed in the annexes of the “Habitats” Directive or Bern Convention (e.g., *Bombina variegata*, *Triturus carnifex*, etc.) (Speybroeck et al., 2018).

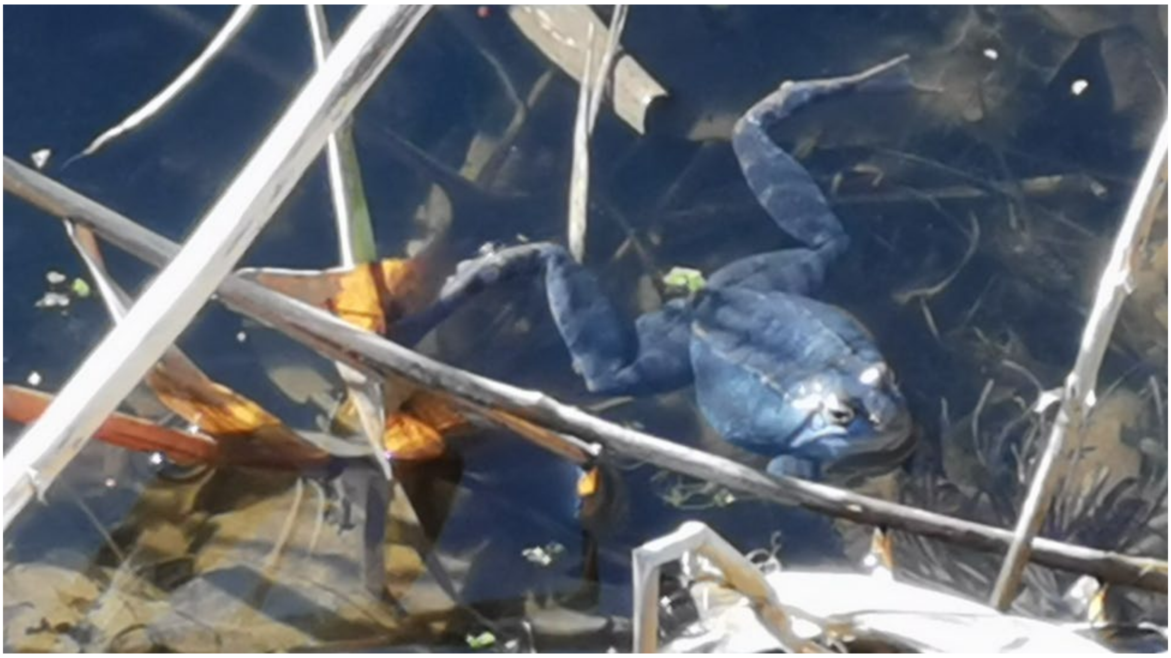

Figure 2.4: The Balkan moor frog (*Rana arvalis*) males shortly display a blue colouration during the mating season; newts, frogs and toads often reproduce in aquatic environments inside wetlands (Sittersdorf, Austria)

2.3.2 Minimal requirements of the survey

Within the framework of the I-SWAMP project, the survey's goal is to **identify the species** present in each site. All data, including random observations or contributions from amateurs, can contribute to this knowledge. However, it is crucial to implement a **standardised survey method** to enable future repetitions and facilitate comparisons of species richness and abundances (Gent & Gibson, 2003; Scott et al., 1994). It should be noted that methods leading to a reliable estimation of population size for a species (e.g., **mark and recapture methods**) are often **time and resource-intensive**, and may not be easily feasible for elusive or rare species (Scott et al., 1994). Additionally, the **timing of surveys** may vary based on the expected species and is sometimes influenced by location or season (e.g., high-altitude sites may not be accessible at the optimal survey moment) (Gent & Gibson, 2003; Scott et al., 1994). When studying water bodies (ponds, peatland pools, streams, etc.), **it is valuable to understand if observed species are successfully reproducing in the breeding sites**. Therefore, recording all observable life stages – from adults to **eggs, to larvae, to newly metamorphosed individuals** – is essential (Scott et al., 1994).
Various methods are available for surveying amphibians (see Scott et al., 1994; Gent & Gibson, 2003): **Visual Encounter Surveys** (VES, where a predetermined path is walked within a set time) (Scott et al., 1994); audio transects (Scott et al., 1994); **transect walks** (where the habitat is sampled along given paths thoroughly investigated with active searches using nets or under logs, rocks, and vegetation) (Scott et al., 1994); **quadrat or patch sampling** (where the habitat is divided into square plots or patches of suitable habitat are identified, and some are randomly and thoroughly investigated) (Scott et al., 1994); sampling with pitfall or funnel traps (usually along with drift fences)(Gent & Gibson, 2003; Scott et al., 1994). Some of these methods can be employed to monitor amphibians in breeding sites, especially VES, transects, funnel traps, and quadrats (Scott et al., 1994). Additionally, some of these methods can provide **useful estimates of population size or density,** especially when coupled with mark and recapture or removal sampling activities (Gent & Gibson, 2003; Scott et al., 1994). The efficiency of these methods may vary based on the target species or habitat types and conditions (e.g., clear or murky water, sparse or dense vegetation) (Gent & Gibson, 2003; Scott et al., 1994).

2.3.3 Suggested protocol

This protocol builds on the protocols suggested by previous authors (see Gent & Gibson, 2003; Scott et al., 1994).

1. **Gather information** from previous surveys, scientific literature, and local or expert knowledge. In many areas, only a small group of species can be expected, but some may be elusive or rare, so it is always useful to rely on what is already known.

2. **Verify if you need permissions or a license** to conduct surveys. This is usually required for protected species and surveys within protected areas, such as Natura 2000 sites, especially when handling or disturbance of animals is expected or

necessary. In some cases, specific survey methods are requested when working with protected species. Simple and non-invasive survey methods can usually be carried out without permissions and are better choices if you want to involve citizen science or amateurs in your monitoring.

3. According to the expected species and the site's condition (snow or ice cover, accessibility, disturbance from anthropic activities), **establish the best timing** for your survey. Pay particular attention to early-breeders such as *Rana temporaria* (Gent & Gibson, 2003; Scott et al., 1994; Speybroeck et al., 2018).

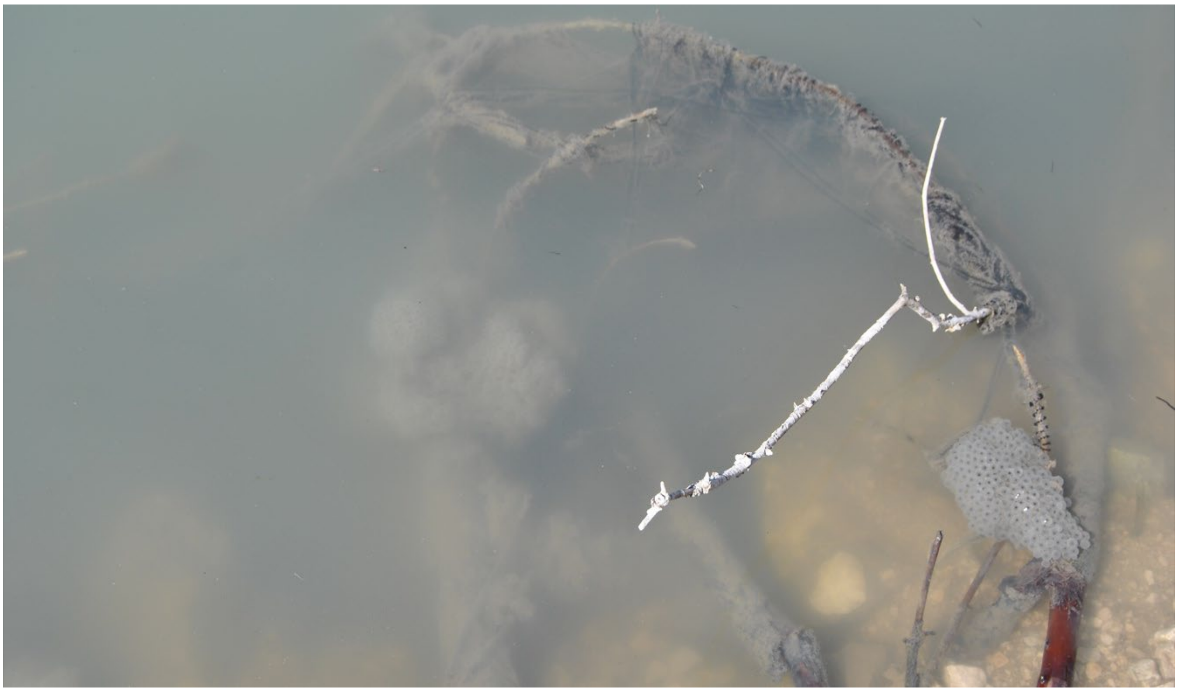

Figure 2.5: Common frog (*Rana temporaria*) spawns (greyish) and common toad (*Bufo bufo*) egg strands (darker) in a shallow lake (San Vito di Cadore, Italy, photo: G. Menegus)

4. If working on a breeding site (pond, peatland pool, system of peatland hollows), **search for adults** in their reproductive period and **eggs** (see **Figure 2.5**)**, larvae, or newly metamorphosed individuals** throughout the season.

    a. For **small habitats with clear water** and sparse vegetation, **Visual Encounter Surveys** (VES) are ideal (Scott et al., 1994). This involves walking around or along the reproductive site, following a predetermined path, counting and/or photographing all individuals or egg-masses (spawns), and noting observed species and life stages (Gent & Gibson, 2003; Scott et al., 1994).. Perform these walks within a set amount of time (e.g., 15 minutes). If the habitat or amphibian populations are too large to confidently count all individuals, you can opt to count only animals seen within a specified distance from observers (e.g., 2 meters) or use quadrat sampling by taking photos of randomly chosen quadrats and counting individuals later.
    b. In case of **murky water and/or dense vegetation**, use **dip-netting** to find and identify species (Gent & Gibson, 2003; Scott et al., 1994). Keep in mind that this method is more invasive and requires disturbance and handling

of animals. Establish a path around or along the habitat, randomly select small sections (1- or 2-m-long), and perform a given number of sweeps (e.g., two 1-meter-long sweeps per section) (Scott et al., 1994).
   c. Actively **search for larvae or eggs** if not easily observed (Gent & Gibson, 2003; Scott et al., 1994).
   d. **Repeat VES** along the season to follow different life stages of each species and the turnover of different species.

5. If working on a site that can host amphibians in their terrestrial phase (or fully terrestrial amphibians), **establish 8 x 8 m² quadrats or 2-meter-wide parallel transects** for thorough amphibian searches (Scott et al., 1994).
   a. Whether quadrats or transects, **choose them randomly and survey them in a limited amount of time**, thoroughly looking under logs, rocks, litter, and vegetation (returning these features to their original position afterward).
   b. **Repeat transects or quadrat sampling** along the season, ensuring to avoid resampling the same transects or quadrats.

6. Organize a minimum of 3 visits. Visit nearby sites.

7. If possible, **avoid handling wild animals**. When necessary, handle them wearing sanitary gloves. Sanitise all equipment with bleach after each survey to reduce the risk of pathogen transmission (Phillott et al., 2010).

2.4 Dragonflies

2.4.1 Introduction

Dragonflies (*Odonata*, including ***Anisoptera***, also called dragonflies, and ***Zygoptera***, also called damselflies) are a conspicuous group of **insects**, typically observed in spring or summer, flying near reproductive sites, usually water bodies (see **Figure 2.6**) (Dijkstra & Schroeter, 2020; Siesa, 2017). The Alpine region hosts approximately **90 species of dragonflies**, each with an **aquatic larval stage and a subaerial, flying adult stage** (Dijkstra & Schroeter, 2020; Siesa, 2017). Both larvae and adults are **predators**, with some species even preying on small fish or amphibian larvae (Dijkstra & Schroeter, 2020; Siesa, 2017). Dragonflies serve as **valuable indicators** for aquatic environments, as they often depend on good water quality (Assandri, 2021; Bonometto, 2020). Different species exhibit varying sensitivity to pollutants or oxygen deficiency (Assandri, 2021; Bonometto, 2020; Flenner & Sahlén, 2008; Hassall, 2015; Rocha-Ortega et al., 2019). The destruction of wetlands can have detrimental effects on dragonfly conservation, given their reproduction in a diverse range of water bodies (with different species utilising different habitat types) (Assandri, 2021; Kalkman et al., 2007, 2018; Clausnitzer et al., 2009; Rapacciuolo et al., 2017).

Due to their conspicuous and aesthetically pleasing nature as flying adults, dragonflies make an **excellent flagship group for conservation efforts**. Additionally, some species are **rare and/or protected**, further emphasising the importance of their protection.

2.4.2 Minimal requirements of the survey

In the context of I-SWAMP, monitoring aims to provide insights into the diversity of the *Odonata* community, **identifying the species present or reproducing in the study sites**. All kinds of data, including random observations, can contribute to this knowledge, but standardisation is recommended. While many species can be easily identified, **reliable identification typically requires a photo and/or capture with a net** (Smallshire & Beynon, 2010). In most cases, **sample collection is not necessary**. Observations of **breeding behaviour** can be obtained from couples displaying mating or mate-guarding behaviours, as well as from **larvae, emerging juveniles or exuviae** (Smallshire & Beynon, 2010). Nevertheless, the majority of information will be derived from the observation of adult dragonflies (Smallshire & Beynon, 2010).

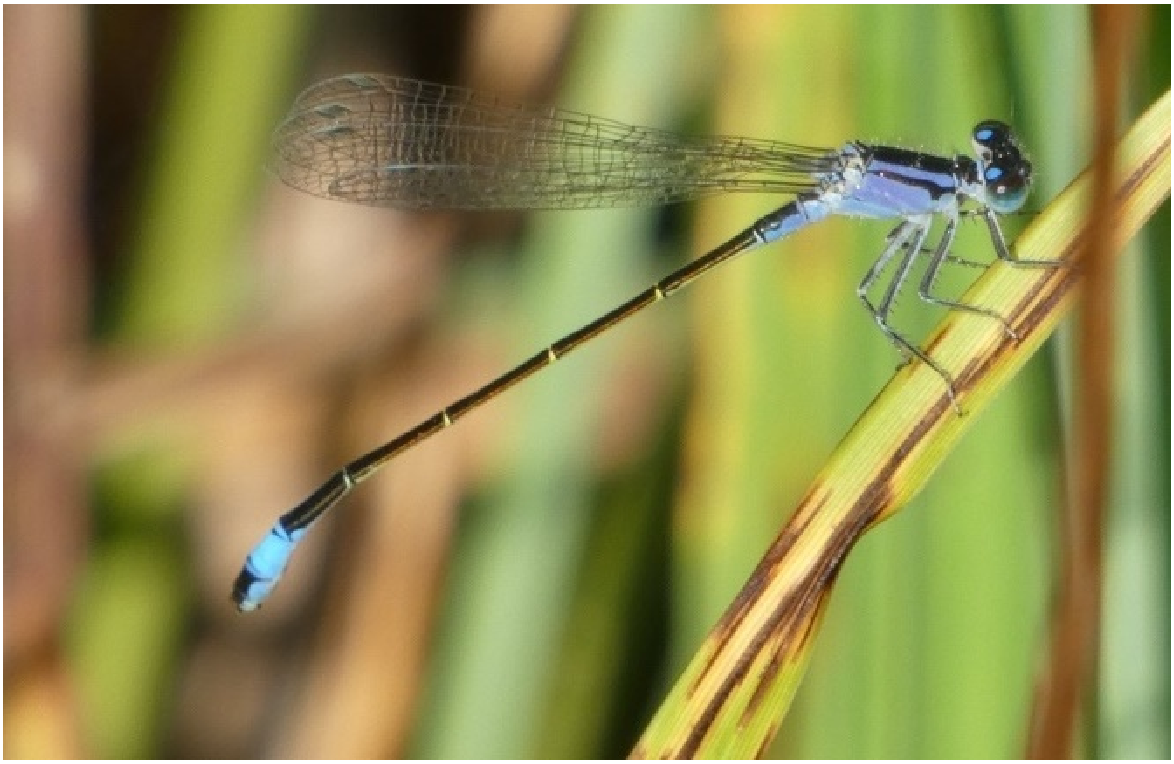

Figure 2.6: *Ischnura elegans* (Lavamünd, Austria, photo: DG)

2.4.3 Suggested protocol

This protocol is similar to the one used by the Dragonfly Monitoring Scheme 2009 Pilot of the British Dragonfly Society (Smallshire & Beynon, 2010).

1. **Gather information** from previous monitoring or literature, also about nearby sites. Keep in mind that **many species are distant flyers** that can cover significant distances and far-apart sites in one day.

2. **Verify if you need permissions or a license** to perform the surveys. Some private sites will require permission to enter. Some species are protected, and working with them or in protected areas may require permission. Surveys that do not cause significant disturbance to the animals (e.g., by photographing them or

observing them) are usually allowed and can be used to involve the public in projects of citizen science.

3. Since many species can be present at a site in different moments of the season, it will be necessary to **visit the site several times** during spring and summer. The timing should also be based on the weather: when possible, surveys should be carried out from 10:30 AM to 4:30 PM, with temperatures ranging from 17° to 30°C, and cloud cover lower than 75% with moderate wind. Slight variation in these parameters can influence the species that could be observed (e.g., most small species will not be able to fly at low temperatures or with too much wind).

Figure 2.7: A female *Anax imperator* during oviposition (Sittersdorf, Austria, photo: D.G.)

4. **If the study site is very small**, such as a small pond, a **path around it can be established** (this method has some similarities with **point count surveys**) (Pearce-Higgins & Chandler, 2020; Smallshire & Beynon, 2010) and then walked in a given amount of time (e.g., 20-30 minutes). All the adults or juveniles observed within a given distance from the observer (e.g., 2 m) should be photographed or, if needed, captured with a butterfly net and examined. This walk should be repeated every 2 weeks/every month. Time recording should be paused when focusing on catching or photographing a specimen.

5. **If the site is larger or more complex**, encompassing different habitats, or there is a system of small patches of suitable habitats (such as a system of ponds or a system of small peatland patches), **transects should be established** (Smallshire & Beynon, 2010) to cover the different habitat types or patches.

a. All animals observed within a **given distance from the observer** (e.g., 2 m) should be captured/photographed and identified. Species with a distinctive appearance may be easily recognized and recorded without capture or photos.
b. The transect should be **500- to 1000-m-long** and be walked in a given amount of time (e.g., 90 minutes).
c. Time recording should be paused when focusing on catching or photographing a specimen. Each transect should be repeated every 2 weeks or every month.

6. **A butterfly net** with a 100-150 cm-long handle and a frame of 35-50 cm in diameter could be used to temporarily capture the adults.

7. The data and observations recorded during the survey should include, when possible, the **species, sex, life stage (young/adult), and behaviour** (mating, mate-guarding, patrolling, foraging, thermoregulation, etc., see **Figure 2.7**).

8. Plan additional survey time to search breeding sites for **exuviae and/or larvae** (see **Figure 2.8**). Exuviae can be collected at the breeding sites either on vegetation or floating on the edges of ponds and pools (Smallshire & Beynon, 2010). Larvae can be collected with aquatic nets used for macrobenthos monitoring (Ghetti, 1997; Campaioli et al., 1994).

Figure 2.8: Exuviae can be useful to understand if a certain species reproduces in a specific site, as in the case of this *Somatochlora alpestris* (photo: G. Menegus)

9. **Random observation or active search in nearby sites** can be very useful to understand which species could visit the study sites and/or breed there.

2.5 Butterflies

2.5.1 Introduction

Butterflies (*Lepidoptera*: *Papilionoidea*) are a **diverse group of insects**, constituting communities in alpine regions with dozens of species that flutter through the air during spring, summer, and autumn (Tolman & Lewington, 2009). These conspicuous insects serve as excellent **flagship species**. **Easily captured and studied with minimal disturbance** using a butterfly net, butterflies are **valuable indicators of habitat quality** or disturbance. They usually rely on plants (and sometimes ants) in their larval stage, while in their adult stage, in most cases, they primarily feed on nectar (Tolman & Lewington, 2009).

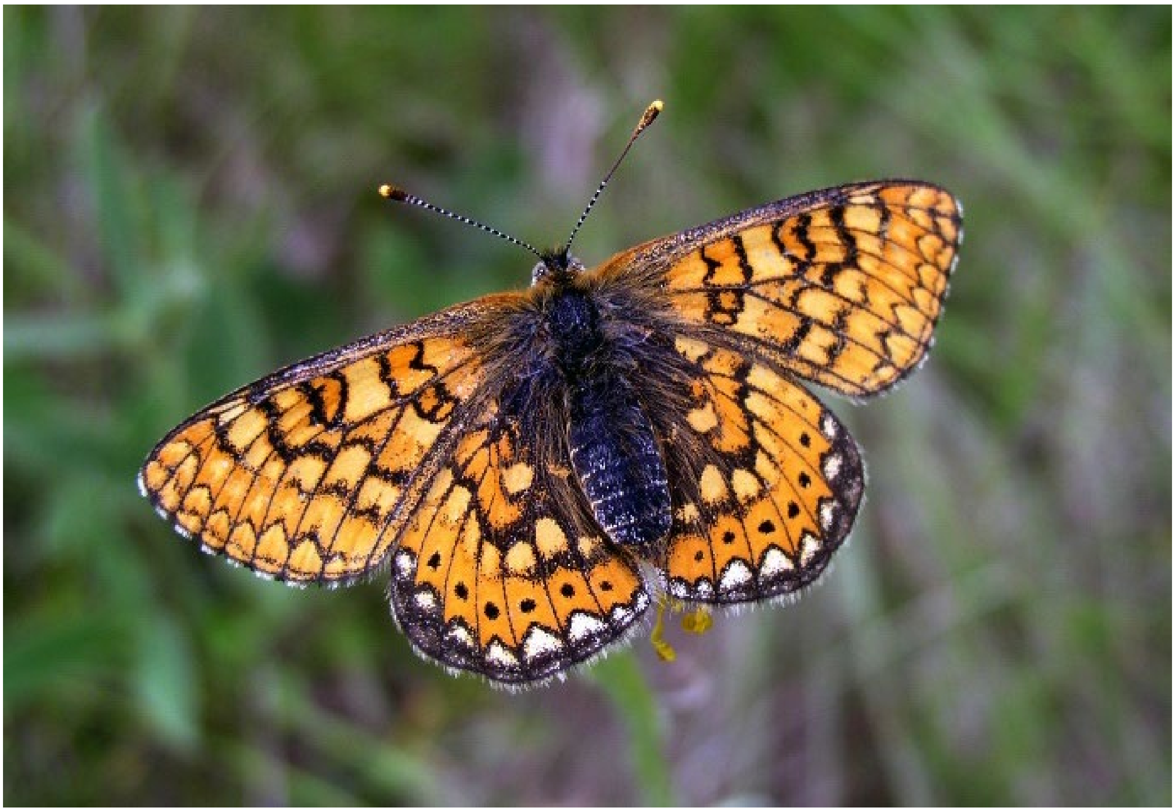

Figure 2.9: The marsh fritillary (*Euphydryas aurinia*) an endangered butterfly listed in Annex II of 92/43/CEE “Habitats” Directive is often found in *Molinia* meadows with *Succisa pratensis* (photo: M. Vernik)

Certain butterfly species exhibit a close **association with specific wetland plants** or habitats, such as peatlands, springs, or wet prairies (see **Figure 2.9**) (Tolman & Lewington, 2009; Weking et al., 2013). This connection makes them effective indicators of wetland quality, especially when their host plants are rare or linked to peculiar conditions (Thomas & Clarke, 2004; Weking et al., 2013). Butterflies, being **well-known and extensively studied** compared to other insect groups, include many species that are endangered and/or protected.

2.5.2 Minimal requirements of the survey

The objective of the I-SWAMP butterfly surveys is to **understand the species composition** present at a designated wetland site. Contributions of all kinds, including amateur or spontaneous observations, can contribute valuable information to this assessment of species richness. Simultaneously, the implementation of **semi-quantitative protocols for assessing both richness and abundance** is crucial for standardisation. This ensures that the survey can be replicated in the future, enabling the comparison of results.

While **many species are easily identifiable**, in most cases, **capturing and/or photographing specimens can be necessary** (Pollard & Yates, 1993; Sevilleja et al., 2019). Some species are visually indistinguishable, making it challenging to identify them with the naked eye. In such instances, the decision to collect a specimen lies with the observer. However, it is imperative to consider that the survey is a component of a conservation project, and efforts should be made to minimise disturbance to local populations. If the considered species are common and/or share similar ecological characteristics, their release may be pursued with minimal loss of information.

2.5.3 Suggested protocol

The method builds on Pollard transects and on the protocols used by the European Butterfly Monitoring Scheme (Pollard & Yates, 1993; Sevilleja et al., 2019).

1. **Collect previous information on butterflies** from prior surveys, literature, local or expert knowledge, or any available data source.

2. **Verify if you need permissions or a license** to conduct the survey, especially in protected areas or when monitoring and handling protected species. Surveys using low-disturbance methods (such as observations or photos) are generally not regulated, making them suitable for involving amateurs or students. Permission is often required for work on private property.

3. Although some species can be observed almost year-round, most have a shorter flight period, necessitating **multiple site visits**. Optimal weather conditions are typically found from 10:00 AM to 4:00 PM, with temperatures ranging from 13°C to 35°C, moderate wind (less than 5 on the Beaufort scale), and preferably low cloud cover (less than 50%), though higher cloud cover is acceptable with elevated temperatures (above 17°C) (Pollard & Yates, 1993; Sevilleja et al., 2019).

4. Use a **net with a 100-150 cm-long handle and a frame of 35-50 cm** in diameter to temporarily capture adult butterflies.

5. Establish **Pollard transects** (Pollard & Yates, 1993; Sevilleja et al., 2019) to observe the butterfly community at the designated site and its surroundings. Ideal configurations include a 500- to 1000-m path that spans different habitat

types (e.g., peatland, wet prairie, forest, pasture, etc.). Each transect should be divided into sections of a specified length (50 to 100 m).

a. **Walk the transect**, identifying, capturing (with a butterfly net), or photographing every butterfly observed within a designated distance (e.g., 2.5 m).
b. **Walk the path within a limited time** (e.g., 90 minutes), pausing time recording when capturing or handling a specimen.
c. When handling a specimen, **take standard photos** of the upper and lower sides of the wings and release the individual.
d. Record **species, sex, wing wear** (from 0-intact to 4-highly damaged), **behaviour** (mating, foraging, thermoregulation, flight, etc.) for each specimen, when possible.
e. **Repeat each transect every 2 weeks** / every month from May to October.

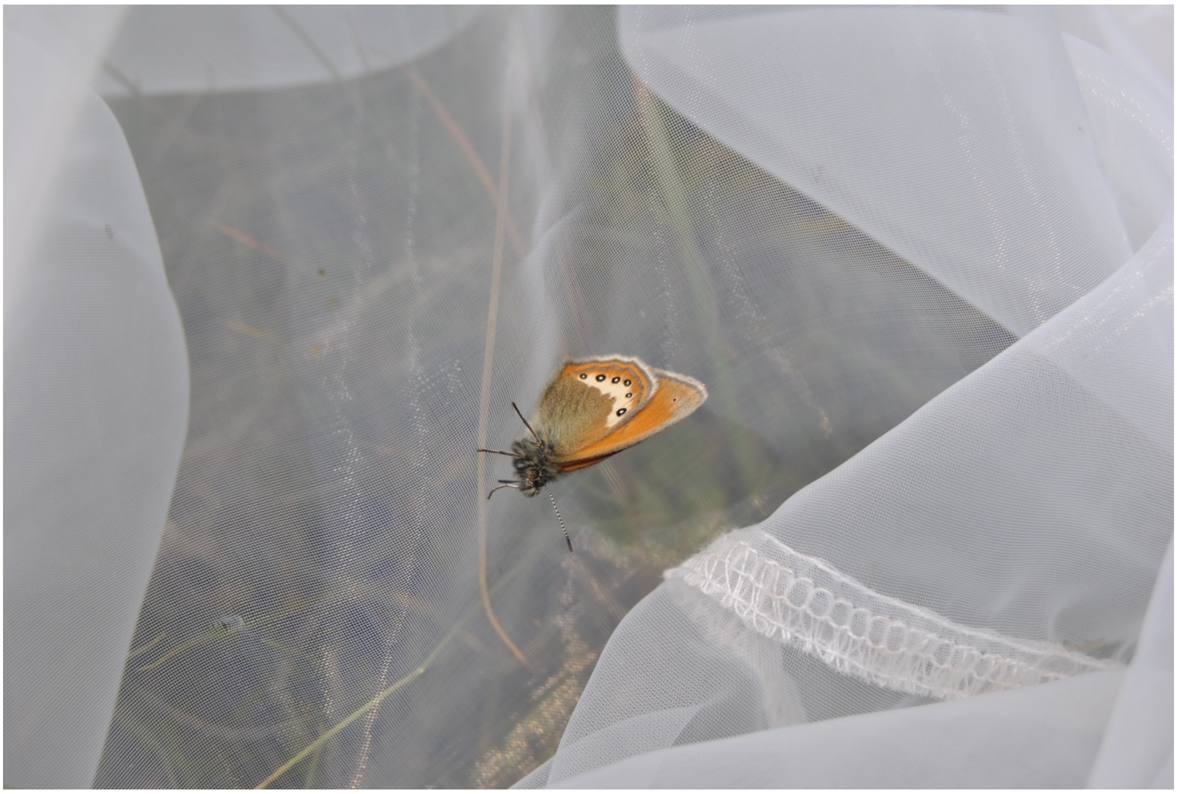

Figure 2.10: Butterflies, generally speaking, can be easily captured with a net and identified at sight or from a photograph, as in the case of this *Coenonympha gardetta* (photo: G. Menegus)

3. Conservation and restoration

3.1 Introduction

Conservation is the scientific discipline dedicated to comprehending, mitigating, and preventing the adverse impacts of human activities on natural habitats and biodiversity. Its primary objective is to **minimise the loss of biodiversity** across various levels, encompassing genetic or population diversity, species diversity, and ecosystem or habitat diversity, as defined by the **Convention on Biological Diversity** (Soulé & Wilcox, 1980; Soulé, 1985).

Effective conservation strategies require a deep understanding of the species, habitats, or ecosystems targeted for preservation, encompassing their status, ecology, threats, and well-established best practices adaptable to diverse situations. The foremost strategy involves **preventing and avoiding damage**s. When prevention is unattainable, **some damages can be partially rectified through restoration** – direct interventions in natural habitats or populations to achieve conservation outcomes (Jordan et al., 1990).

Conservation and restoration become imperative when human activities or their indirect consequences negatively impact nature, including **habitat destruction** or fragmentation, **pollution**, **invasive species** introduction, **overexploitation**, and changes induced by **global warming** (Maxwell et al., 2016). These situations can disrupt natural population dynamics and ecological successions, altering ecological and evolutionary processes (Maxwell et al., 2016). During interventions, choices must be made regarding the target situation, aiming for habitats supporting diverse species or favouring rare habitats sustaining endangered species. Conservation efforts may also focus on protecting and restoring single species or promoting habitats characteristic of specific landscapes.

These principles are applicable to wetland conservation, including the conservation of **small Alpine wetlands**. These habitats, vital, rare, and endangered, host a significant portion of regional diversity, offering crucial ecosystem values and services to communities. **The Alpine region faces common pressures and threats** to various wetland types (Assandri, 2021; Bonometto, 2020). Many species of regional or community interest are rare but distributed widely across the region, needing coordinated actions in different Alpine areas for effective conservation.

The subsequent paragraphs delve into various habitat or ecosystem types separately, highlighting specific pressures or statuses and proposing potential solutions or management strategies. It's crucial to note that **in most cases, multiple habitats coexist and blend** (Keddy, 2010), making clear distinctions challenging. In such instances, conservation efforts should consider protecting multiple habitats simultaneously, adapting interventions accordingly. Nonetheless, specific cases are outlined.

3.2 Ponds and small lakes

3.2.1 Introduction

In the context of small **shallow water bodies**, whether they are **permanent or temporary**, a comprehensive approach involves gathering information about various aspects. This includes data on vegetation, with a specific focus on the presence of invasive, rare, or endangered species. Additionally, understanding the habitat type, as categorised by the 92/43/CEE "Habitats" Directive, is essential. Moreover, some key animal groups, such as dragonflies and amphibians, should be considered in the assessment.

It's important to determine whether the water body is isolated or part of a larger system. Factors like overshadowing, potential usage by cattle or other livestock, and the presence of tourism or fishing activities should be investigated.

3.2.2 Excessive livestock trampling

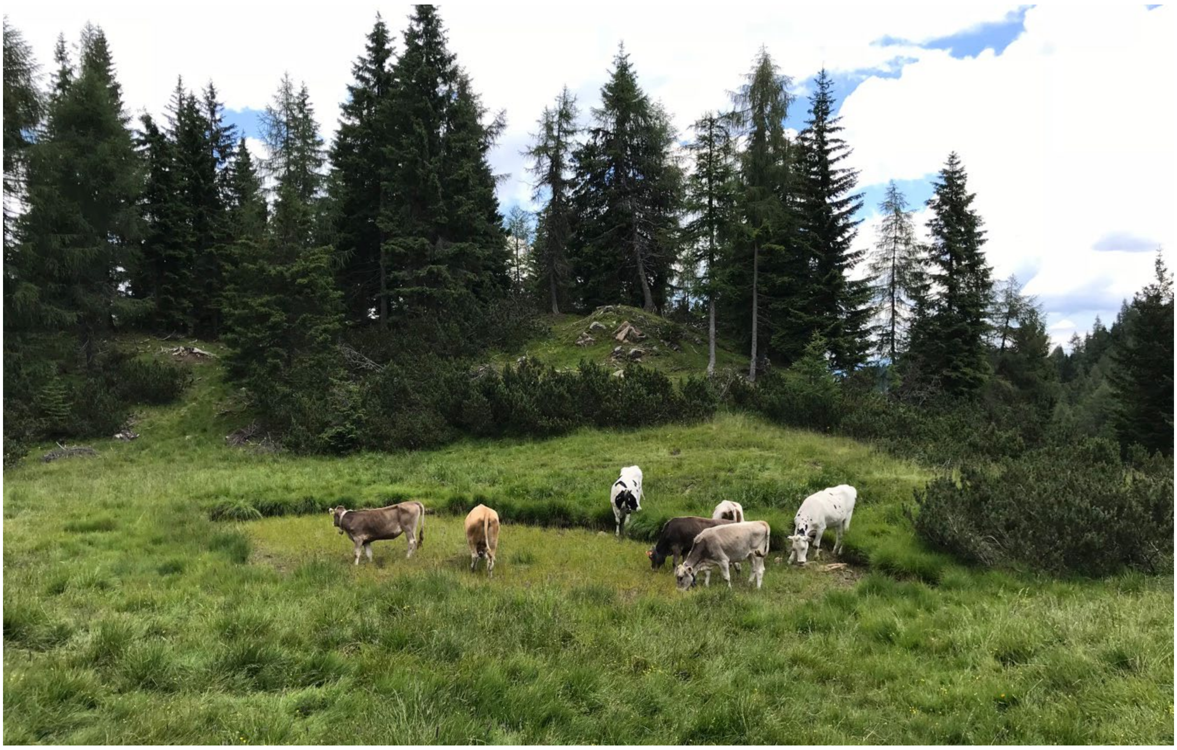

Figure 3.1: A dry pond, heavily trampled by cattle (Lozzo di Cadore, Italy, photo: L. Bonometto)

3.2.2.1 What to expect?

The trampling of small water bodies by cattle (see **Figure 3.1**), horses, or sheep can result in significant damage, particularly impacting bankside vegetation and the adjacent habitats (Bonometto, 2020). Evidence of such impact is often observed through the **presence and/or dominance of plant species that exhibit resistance to trampling**

or thrive under such conditions. These plants typically possess leathery leaves and may also benefit from other factors associated with the presence of animals, such as herbivory or eutrophication. An illustrative example is *Deschampsia cespitosa*.

3.2.2.2 What to do?

In this case, implementing **exclusion** measures is recommended. This can be achieved through the **installation of wooden or electric fences**. An effective fence design consists of two wires, one positioned at 50 cm height and the other at 1 m height (see **Figure 3.2**). Beyond preventing livestock access, these fences also serve the purpose of signalling the presence and significance of the habitat to people. Additionally, they can help exclude other animals, such as hogs.

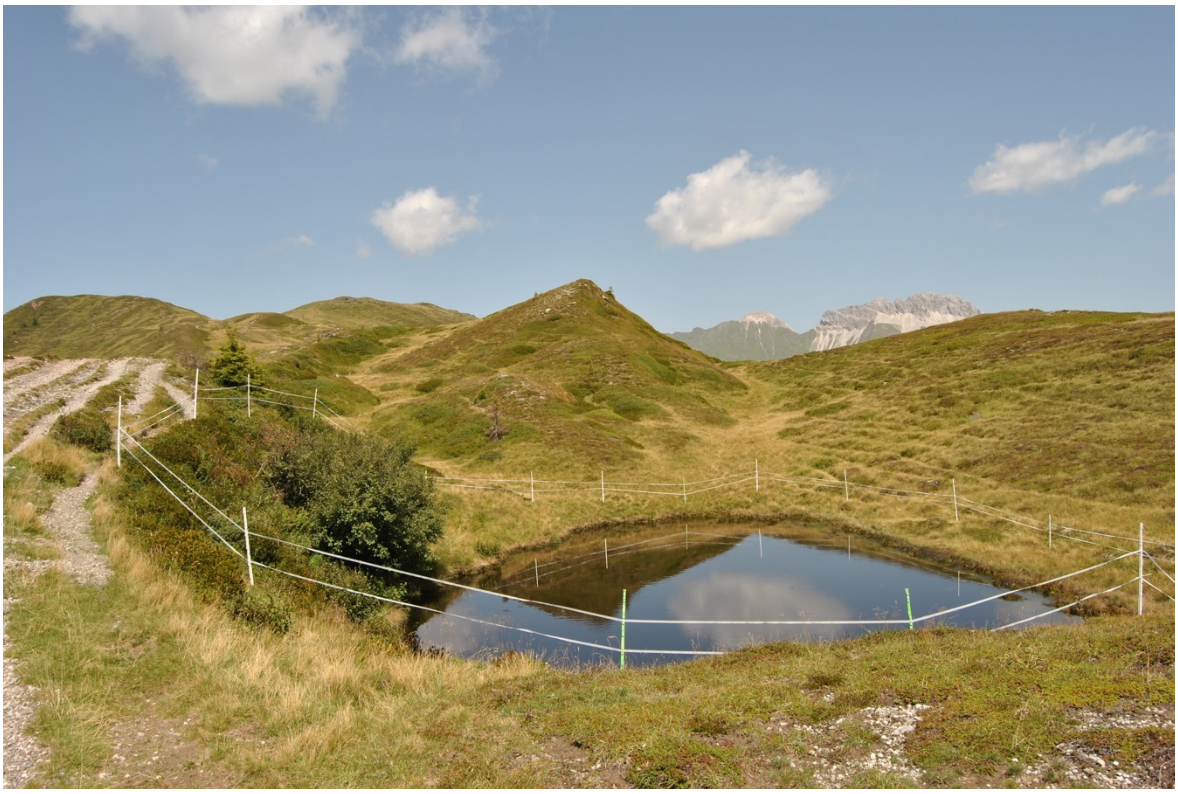

Figure 3.2: An electric fence can be an effective way to exclude livestock from a sensitive area (Comelico Superiore, Italy, photo: G. Menegus)

If the pond is surrounded by other wetland habitats like wet prairies or peatlands, it is advisable to **consider incorporating parts of the adjacent habitats within the fence**. This approach provides a buffer zone for the pond and protects different habitats. The fence should remain operational whenever grazing animals are present, typically from May-June to October. In cases where the site is not utilised during the winter, removing the fence in the cold season can allow the area to be accessible to wildlife.

To mitigate the presence of plants favoured by trampling, targeted or **periodic mowing** is recommended at the end of the season (e.g., late August or September). The mowing operation should be carried out with lightweight equipment, and grass clippings should be placed downstream of the pond. Focus on mowing **no more than a quarter of the area.**

Communication and coordination with stakeholders, such as shepherds or landowners, are crucial aspects to consider.

3.2.2.3 Problems

If the pond serves as a trough for livestock, and there is no alternative water source available, you may consider **building an artificial trough**: provide small artificial troughs downstream from the pond. This ensures that the livestock have access to water while allowing you to protect the pond and its surrounding habitat. If this is not feasible, you should consider **fencing most of the pond** but leaving a small access point for animals. Choose a location for access that has either no vegetation or already degraded vegetation.

If the pond is part of a system of ponds, you can **fence a small group of them**. Consider fencing only a small group of ponds, either along a transect or at regular intervals. This way, you maintain water troughs for the animals while ensuring the protection of habitats. Prioritise fencing ponds that exhibit interesting flora and fauna or those that are less degraded. This approach contributes to conservation efforts without compromising the water needs of livestock. **Coordination with relevant stakeholders is key** to implementing these measures effectively.

3.2.3 Eutrophication

3.2.3.1 What to expect?

Eutrophication (the **excess of nutrients in water and soil** leading to the accelerated growth of algae, aquatic, and terrestrial plants) is commonly associated with the **presence of cattle or other livestock**, as well as their manure. In some instances, traditional practices, such as depositing compost in ponds or streams or fertilising fields upstream of wetlands, can contribute to this phenomenon. This excess nutrient situation adversely affects both vegetation and fauna: the banks and aquatic environments often become dominated by **a limited number of rapidly growing or ground-covering plant species**, thriving on elevated levels of nitrate or phosphorus (e.g., *Deschampsia cespitosa* and *Phragmites australis*). Simultaneously, the aquatic environment tends to be murky and warm during the day, with reduced oxygen levels. This leads to a decline in the aquatic community, affecting both plants and animals, with a prevalence of species adapted to disturbed environments, such as the dragonfly *Libellula depressa*.

3.2.3.2 What to do?

In this case, the recommended strategy is to implement **fencing around the sites** (refer to **3.2.2.2**) and carry out **periodic mowing** (once a year at high altitudes – above 1500 m – and twice a year at lower altitudes), preferably towards the end of the season, with the removal of clippings. It is crucial to **refrain from mowing more than a quarter of the banks**.

In cases where eutrophication results from the dumping of compost or grass clippings into the pond, you should **prevent it informing stakeholders effectively**, installing signs discouraging the disposal of compost, and raising awareness about the ecological consequences associated with such actions.

3.2.3.3 Problems

If the aquatic environment is dominated by a few rapidly growing species, it is advisable to address this issue by **reducing their populations**. You should cut these species at the end of the dry season using lightweight equipment and ensuring the removal of clippings. **Avoid mowing more than a quarter of the habitat**.

For additional guidance, please refer to **3.2.2.3**.

3.2.4 Invasive plant species

3.2.4.1 What to expect?

Figure 3.3: Bamboo (*Bambusoideae*, on the right) spreading on the banks of a pond; dumping garden clippings or compost in wetlands or streams can enhance the dispersal of invasive species (Lavamünd, Austria, photo: S. Glatz-Jorde)

Invasive species are defined as **introduced species that proliferate, causing harm to their new environment.** This often results from competition with local species for resources such as light, nutrients, and space. Whether their introduction is intentional or accidental, invasive species can pose a **significant threat to local biodiversity**, necessitating management efforts. Many plant species have been introduced to both aquatic and terrestrial environments, with some becoming dominant in various ecosystems and leading to the loss of locally rare or endangered species. *Elodea canadensis* and *Myriophyllum spicatum* serve as notable examples of invasive species in ponds and small lakes. Other species can be present on the banks (e.g., *Bambusoideae*, see **Figure 3.3**).

Certain activities, such as **the dumping of compost or aquarium waste into ponds** or streams, **can facilitate the dispersal** of invasive species.

3.2.4.2 What to do?

Invasive plants can be effectively countered through **general interventions aimed at restoring natural conditions** (disturbance regimes, water levels, and trophy, etc.). These measures promote more resistant and resilient communities, creating an environment less susceptible to invasion compared to disturbed habitats.

It is also crucial to target such species **mowing or removing them** (Sayer et al., 2023): the specific strategy depends on the species in question, its population size, and the season. In general, these plants **should be cut before they produce seeds**, and, if possible, for aquatic plants this should done towards the end of the dry season. If you suspect that **stakeholders or landowners are disposing of compost or aquarium waste in ponds** or other aquatic environments, **you should prevent it with proper information** dissemination, placing signs to discourage such practices, and raising awareness about the ecological consequences of these actions.

3.2.4.3 Problems

Some species may necessitate more intensive and prolonged management (e.g., *Myriophyllum* sp., *Elodea* sp.): in these cases, national or regional guidelines are usually available.

3.2.5 Fish

3.2.5.1 What to expect?

Fish are not naturally present in small Alpine water bodies, especially at high altitudes and in isolated sites. Their introduction, often done to foster **recreational fishing**, can result in the **loss of numerous species** in their newfound habitat. Some **amphibians, dragonfly or damselfly larvae, crayfish**, and other species **are not adapted to the presence of predatory fish**, and their vulnerable populations can be easily wiped out. The introduction of fish, such as trout, has been associated with the disappearance of many populations of the dragonfly *Leucorrhina dubia* (Bonometto, 2020). Moreover, fish introduction can bring about **changes in the plant community and water quality**.

3.2.5.2 What to do?

Most **introduced populations are not viable in the long term**, if not sustained via periodic reintroduction: **you should consider stopping the release of fish**, coordinating with the authorities or associations that manage such releases (fishing authorities, fishing clubs, etc.). **Eradication of introduced fish** is also a possible, more expensive, solution.

3.2.5.3 Problems

If eradicating or halting the introduction of fish is not feasible, you should **create nursery or shelter areas for aquatic wildlife**. These areas should have shallow water and denser vegetation, making them suitable for the survival of larvae and adults while discouraging the presence of fish.
If you suspect of people releasing fish without permission, it is essential **to inform local stakeholders** about the ecological consequences of such actions.

3.2.6 Tree overgrowth (shadow and isolation)

3.2.6.1 What to expect?

Over time, **the natural growth of trees and the expansion of forested areas can result in the isolation or overshadowing** of small water bodies (see **Figure 3.4**). This phenomenon may occur as part of natural ecological successions or due to land management practices, such as the abandonment of pastures or hay meadows. While this is not necessarily problematic, it can lead to some issues, particularly if it results in **landscape homogenization and the isolation of animal populations** (Langton et al., 2001; Sayer et al., 2023).

For instance, **when a pond** that was originally situated in an open environment **becomes surrounded by rapidly growing forest**, it **can isolate insect populations that require light corridors for flight**, particularly dragonflies (Bonometto, 2020). This isolation can disrupt metapopulation dynamics, resulting in smaller and more vulnerable populations.

Moreover, **in areas where only a few ponds are present**, the existence of **ponds completely overshadowed by trees can lead to the loss of specific habitats** that would benefit from higher temperatures and increased light. This loss can have implications for vegetation, animal populations, and water temperature and quality.

3.2.6.2 What to do?

In this situation, **it is essential to establish open areas with light corridors** connecting ponds to nearby open habitats, including pastures, streams, rivers, lakes, roads, ski slopes, other wetlands, etc. These light corridors can be created by **selectively cutting the minimum number of trees** necessary to connect the pond to existing corridors.

Figure 3.4: Over time, trees and shrubs can overshadow and isolate ponds, which can be problematic for many groups, including dragonflies (Lavamünd, Austria, photo: S. Glatz-Jorde)

While **the presence of shaded areas is generally not problematic**, it's crucial **to avoid a situation where all ponds in a given area are entirely overshadowed** (Langton et al., 2001; Sayer et al., 2023). If required, selective tree cutting can be employed to **ensure that certain areas of the pond receive sunlight during the morning and central hours of the day in summer** (Sayer et al., 2023). Balancing both shaded and well-lit areas is beneficial for sustaining a diverse array of species, and **it does not necessitate a complete clear-cutting approach.**

3.2.6.3 Problems

If there are numerous isolated or overshadowed ponds in an area, you should **consider restoring only a selection** of them. This could be implemented along a transect or at regular intervals, with a priority given to ponds that can be easily connected to nearby open areas. This is particularly crucial if these open areas host other wetlands or valuable meadows.

3.2.7 Low water level

3.2.7.1 What to expect?

The presence of standing water for at least part of the season defines water bodies (including ponds and shallow lakes). This doesn't necessarily imply that water should persist throughout the entire season, as temporary ponds that undergo periods of drought and water abundance contribute to habitat diversity. However, **excessive water resource use and insufficient precipitation**, including snow and rain, **can lead to the transformation of permanent ponds into temporary ones**. This transition may have **adverse effects on local biodiversity**, particularly for species adapted to or dependent on a continuous presence of standing water. For example, the survival and development of newts, frogs, and toads' eggs and larvae depend on water availability. Additionally, certain aquatic plants like *Glyceria notata* or *Alopecurus aequalis* may proliferate in ponds experiencing frequent cycles of flooding and drought, while fully aquatic plants might face disadvantages.

In some instances, **minor structural damages to ponds can enhance water discharge**, such as those caused by small collapses in the pond banks.

3.2.7.2 What to do?

If the low water level is a consequence of a minor collapse in the pond banks, you can **build a small dam**. For smaller ponds with an anticipated low water level, a plywood dam can be employed (see Simila et al., 2014). This involves using two plywood boards, cut higher and larger than the targeted dam area, placed into two parallel grooves in the soil or hammered into place (Simila et al., 2014). The space between the two boards is then filled with earth or peat (Simila et al., 2014). For larger collapses, more elaborate dam structures may be required.

If the low water level results from excessive water extraction, it is advisable to **contemplate a reduction in water extraction** from the site or the upstream water bodies, sources, or aquifers that contribute to it. **Coordination with relevant authorities** and owners with influence on water extraction is crucial for implementing such measures.

3.2.7.3 Problems

If water extraction from the site is conducted by private landowners, it is recommended to **inform them about the ecological repercussions** of these actions.
If the extraction is unlawful or unauthorized, you should **report the matter to relevant authorities**.

If the diminished water level is attributed to climate change-induced alterations in the precipitation regime, more extensive interventions on the sites to mitigate water discharge may be considered.

3.3 Peatlands (fens, bogs, transition mires)

3.3.1 Introduction

Peatlands are wetlands **characterised by peaty soil formation in cool environments**, where the water level remains stable near the soil surface (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 20019). In such conditions, dead vegetation accumulates, forming peat (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 20019).). Two primary types of peatlands are **fens and bogs** (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). **Fens** are dominated by grass-like and sedge vegetation, have a shallow peat layer, pH greater than 6, and are usually fed by surface or groundwater (Keddy, 2010, McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). **Bogs**, on the other hand, are characterized by bog mosses, sedges, ericaceous shrubs, and sometimes evergreen trees (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). They have a deeper peat layer, pH lower than 5, and are primarily fed by precipitation (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). Peatlands with intermediate characteristics are referred to as **transition mires**.

Peatlands are complex and fragile ecosystems that play a crucial role in **carbon storage** (Keddy, 2010; Schumann & Joosten, 2008). You should gather information about vegetation, especially the presence of rare or endangered species and those indicating pressures like eutrophication or low water levels. Additionally, knowledge about various animal groups such as butterflies, amphibians, and dragonflies, particularly in peatlands with pools or streams, is crucial. Understanding the site's connectivity with other peatlands, its use by livestock, any modifications, or changes in management practices is vital for a comprehensive assessment.

3.3.2 Excessive livestock trampling and eutrophication

3.3.2.1 What to expect?

Peatlands typically are not a rich source of nutrients for livestock, due to the poor nutritional content of their vegetation (Keddy, 2010). However, **they are occasionally used by animals for drinking water**, and grazing can occur.

Trampling by cattle, horses, or sheep **can result in severe damage** to small peatlands, adversely affecting vegetation, water quality, and the structure of the peaty soil (McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). This is evident through the **presence of plant species that can withstand trampling** or are favoured by it. In bogs, **damages to the characteristic hummock/hollow structure** are also observed.

Simultaneously, **animal excrements contribute to increased nitrogen and phosphorus levels** in the usually oligotrophic water and soil of peatlands, leading to **eutrophication**. This is indicated by **a reduced plant community and the presence of**

nitrophilous wetland plants like *Deschampsia cespitosa* or *Phragmites australis*, sometimes forming extensive monospecific stands.

It is important to note that **eutrophication can also result from various human activities**, such as the release of fertilizers or other nutrient sources (dumping of compost or grass clippings, blackwater) into the peatland or upstream, leading to similar effects (McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019).

3.3.2.2 What to do?

The optimal solution in this case is to **prevent access by implementing electric fences** (Schumann & Joosten, 2008), as detailed in section **3.2.2**. Fencing can be applied to the entire area or at the entry points to the site. **If complete fencing is not feasible**, priority should be given to **enclosing the best-preserved sections of the peatland**, particularly those hosting rare or endangered species and the upstream parts. In cases where no pools or alternative water sources are available for livestock, fencing the area without electrification may also be considered.

For sites containing stands of nitrophilous species like *Phragmites australis*, **regular mowing is recommended**, at least twice a year at lower altitudes (McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). Utilise lightweight equipment for mowing, and conduct the activity in the latter part of the vegetation period or even when the soil is frozen. Ensure that the clippings are removed and placed downstream of the peatland.

Remember that reeds play a vital role as breeding habitats for birds. Therefore, mowing should only be conducted if it contributes to the restoration of rare peatland vegetation.

3.3.2.3 Problems

If eutrophication is caused by activities upstream of the peatland, your efforts should **focus on preventing these activities** through regulations and by informing all involved parties about the significance of peatlands and the ecological consequences of their actions McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). **Coordination with relevant stakeholders and authorities** is essential for effective implementation. **Encouraging sustainable practices and promoting awareness** about the ecological value of peatlands can contribute to long-term conservation efforts.

3.3.3 Invasive plant species

3.3.3.1 What to expect?

Invasive species (e.g., *Solidago gigantea*, *Solidago canadensis*, etc.) pose a **significant threat to peatlands**, particularly **when combined with other existing pressures** such as eutrophication or low water levels (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). The introduction of invasive species, whether intentional or accidental, can result in the proliferation of **invasive plants that compete with native species**. Certain activities, such as **dumping compost in peatlands or streams, may facilitate the spread of invasive species**.

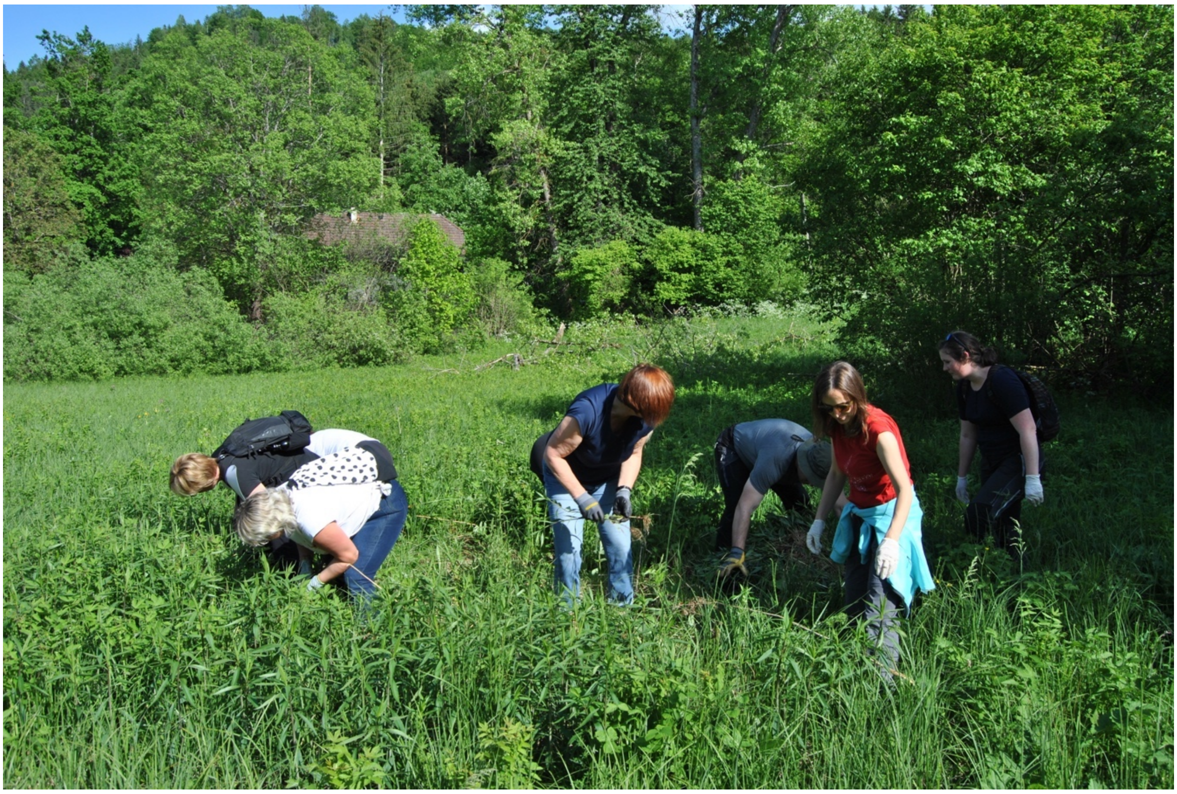

Figure 3.5: Peatlands can be invaded by alien species such as the *Solidago gigantea* and *Solidago canadensis*; these species should be periodically removed with lightweight equipment before they produce seeds (Sittersdorf, Austria, photo: G. Menegus)

3.3.3.2 What to do?

Refer to section **3.2.4.2**. Keep in mind that invasive species tend to thrive in peatlands already affected by other pressures: your efforts should address these factors too (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019).

3.3.3.3 Problems

Refer to **3.2.4.3**.

3.3.4 Low water level

3.3.4.1 What to expect?

The presence of a somewhat stable water level is a crucial environmental factor for the formation of peatlands (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). In fens, water typically originates from springs or aquifers, while in bogs, precipitation is the primary water source (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). To safeguard a peatland site, **it becomes essential to protect both the water sources and the intrinsic features of the site** that contribute to maintaining a stable water level within the peatland (Keddy, 2010; McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019).

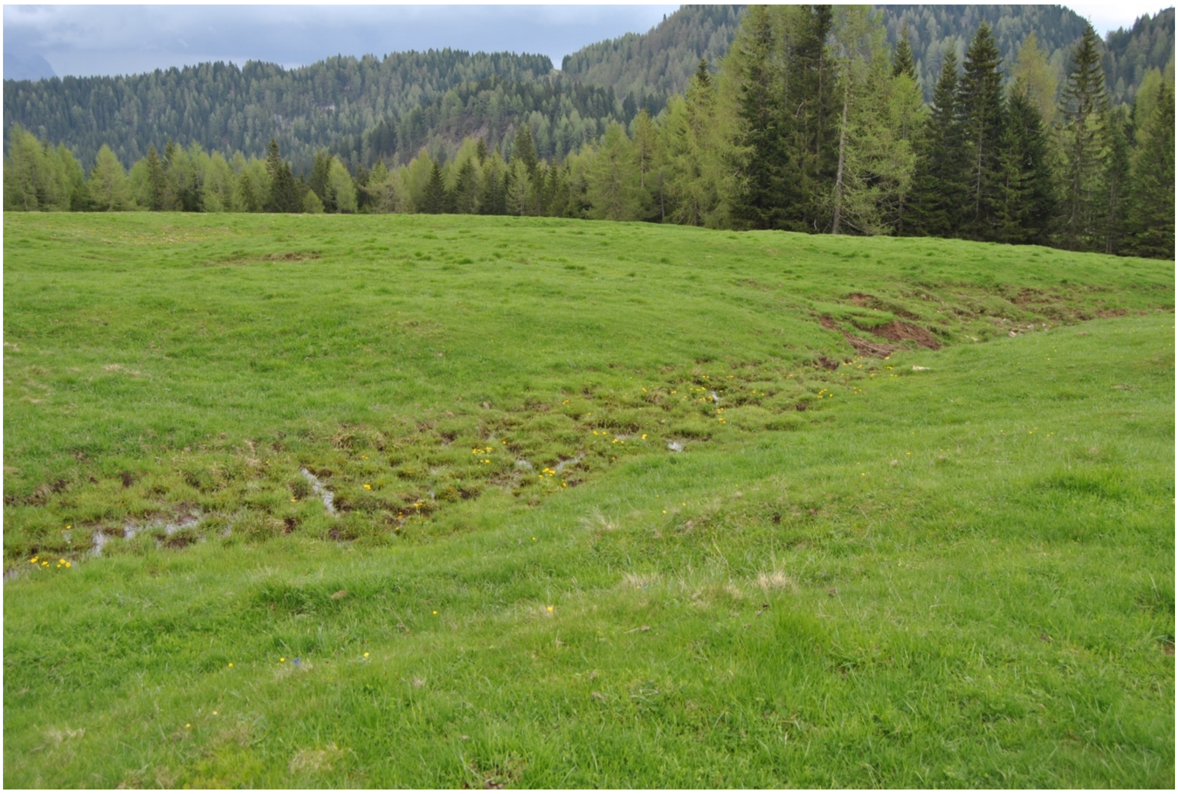

Figure 3.6: Drainage ditches can effectively lower the water level in peatlands, paving the way for marsh, wet meadow or invasive species (Lozzo di Cadore, Italy, photo: G. Menegus)

If the water level is too low, **the peatland is prone to invasion by plants adapted to wet meadows or marshes** (see **Figure 3.7**) (McBride et al., 2011; Schumann & Joosten, 2008; Thom et al., 2019). Additionally, **inadequate water levels accelerate the degradation of peat**, causing increased nitrogen and phosphorus availability in the soil (McBride et al., 2011; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). **Peat mineralisation**, the process responsible for this, **can impede the reestablishment of peatland vegetation** even when water levels are restored (McBride et al., 2011; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019).

Several factors contribute to low water levels, including **overexploitation of water resources extracted upstream**, **reduced precipitation** due to **global warming**, and **direct interventions** on sites (McBride et al., 2011; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). One prominent example is the implementation of **drainage ditches**, V-shaped channels that lower water levels in wetlands to reclaim land for agriculture or pastures, disrupting the natural hydrological environment of peatlands and leading to drier conditions (see **Figure 3.6**) (Quinty & Roquefort, 2003; Simila et al., 2014). These ditches are recognisable as **non-natural systems of straight grooves**.

3.3.4.2 What to do?

If the insufficient water level is caused by human intervention, you should **locate and close drainage ditches** (Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Simila et al., 2014; Thom et al., 2019). The process involves careful monitoring of water levels and assessing potential impacts on adjacent land use (Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). You can close ditches by **constructing small dams**, preferably made from plywood and peat for smaller ditches (Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Simila et al., 2014; Thom et al., 2019). This involves using two plywood boards, cut higher and larger than the targeted dam area, placed into two parallel grooves in the soil or hammered into place (Simila et al., 2014). The space between the two boards is then filled with earth or peat (Simila et al., 2014). **For larger ditches, concrete, wood, or sheet piles may be necessary** (Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Simila et al., 2014; Thom et al., 2019). The placement of dams along a ditch should consider the peatland's slope, ensuring a 10-15 cm elevation difference between consecutive dams (Quinty & Roquefort, 2003; Simila et al., 2014; Thom et al., 2019). This approach fosters increased water levels within the peatland, extending up to 15 meters from the ditch, creating small ponds beneficial for amphibians, dragonflies, and aquatic vegetation (Simila et al., 2014).

3.3.4.3 Problems

If human activities are responsible for the low water level, you should **prevent these activities** through informative engagement with multiple stakeholders. Collaborating with landowners to identify feasible restoration areas that do not impact settlements is crucial. **Inform all relevant actors** about the significance of peatlands in providing ecosystem services and the ecological repercussions of their actions. **Coordination with stakeholders and authorities is essential.** You should raise awareness among stakeholders about the carbon storage capacity of intact peatlands and the imperative of implementing measures against climate change.

Figure 3.7: The combined effect of drainage and eutrophication favour the expansion of *Phragmites australis* in peatlands (Danta di Cadore, Italy, photo: G. Menegus)

It's important to note that **for complex situations**, such as large peatlands (over 2 ha), extensive historical drainage, past use for peat extraction, or mineralised peat, **more complex interventions are required**, and these are not covered in this document (see Quinty & Roquefort, 2003; McBride et al., 2011; Schumann & Joosten, 2008; Simila et al., 2014, Thom et al., 2019).

3.3.5 Tree or shrub overgrowth

3.3.5.1 What to expect?

Over time, **peatlands can be invaded by tree or shrubs species,** generally **favoured by low water levels** and abandonment of traditional management (see **Figure 3.8**) (McBride et al., 2011; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). This can happen also as a natural succession. Starting from the edges, **wooded areas can expand within a few years**, **reducing the surface area** of the peatland and **isolating it from nearby open environments**, with repercussions on various species groups, including dragonflies.

Figure 3.8: Over time, bogs can be invaded by trees and shrubs (Šumeč, Slovenia, photo: B. Stupan)

3.3.5.1 What to expect?

In this case, **it is advisable to slow down the encroachment of wooded areas through periodic cutting** (every 2-3 years) (McBride et al., 2011; Quinty & Roquefort, 2003; Schumann & Joosten, 2008; Thom et al., 2019). The cutting should be done at the end of the season, **using lightweight equipment**. Alternatively, in certain cases, it may be possible to access the bogs **with some machinery during winter** when the ground is frozen (see **Figure 3.9**). The cutting should be limited to what is necessary, **avoiding a clear-cutting** approach. It is important to take action in a timely manner, targeting the rejuvenation of trees and shrubs when they are not yet too large.

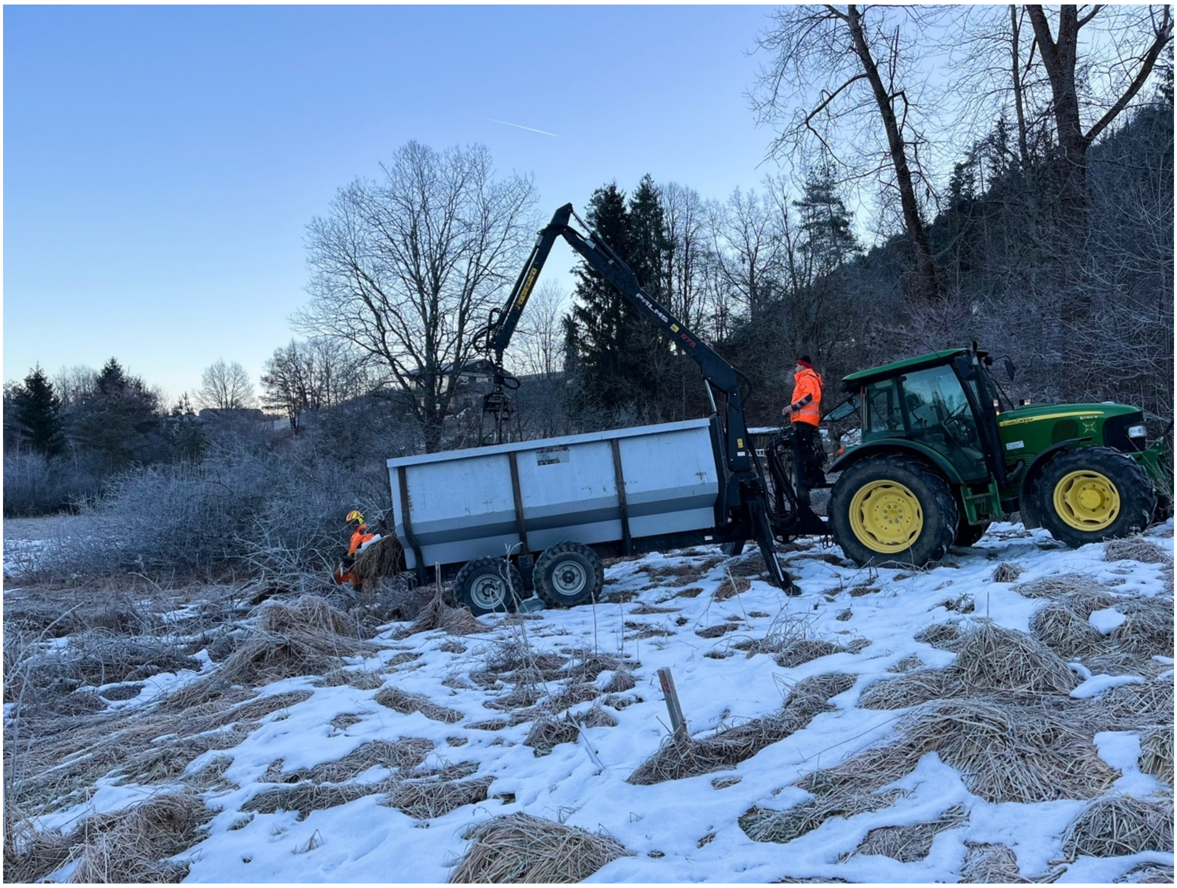

Figure 3.9: Access to peatlands with heavy machinery for the removal of trees and shrubs is advisable only if the ground is frozen (Sittersdorf, Austria, photo: S. Glatz-Jorde)

3.3.5.1 Problems

If much of the peatland is now covered with shrubs and trees, and a complete restoration is not feasible or advisable, **you should try to preserve at least the remaining parts**. This can be achieved by partially expanding open habitats and connecting various parts of the peatland with bright corridors, linking them to nearby wetlands or open areas.

Attention! In some cases, the presence of *Pinus mugo*, *Betula pubescens*, *Picea abies*, and other species in a bog environment indicates the presence of **habitat type 91D0*** "bog woodland", which is protected by the 92/43/CEE "Habitats" Directive. This habitat is really rare and important. In these cases, **seek the advice of a specialist** in peatland conservation. Focus on peatland sites where it is known that the expansion of wooded areas has been rapid, recent and facilitated by human interventions.

3.4 Marshes

3.4.1 Introduction

A **marsh i**s a type of wetland ecosystem characterised by **poorly drained mineral soils and plant life dominated by rooted and emergent grasses** (Keddy, 2010). This sets marshes apart from swamps, where the plant life is primarily composed of trees (refer to section **3.6**) (Keddy, 2010). Marshes are prone to frequent flooding, exhibiting significant fluctuations in water levels throughout the year (Keddy, 2010). The number of plant species in marshes may be limited compared to other wetlands. Grasses, grass-like sedges, and reeds or rushes play a vital role (Keddy, 2010).

Marsh grasses and other herbaceous plants thrive in waterlogged yet nutrient-rich soil, often deposited by rivers (Keddy, 2010). The roots of these plants bind to the muddy soil, impeding water flow and promoting the expansion of the marsh. These waterlogged habitats can harbour diverse ecosystems, with dominance of submersed, floating-leaved, or emergent vegetation, including cattails (*Typha* sp.), pondweeds (*Potamogeton* sp.), sedges (*Carex* sp.), rushes (*Juncus* sp.), and various other plant species (Aeshimann et al., 2011; Keddy, 2010).

3.4.2 Hydromorphological changes

3.4.2.1 What to expect?

Alterations in the water regime of marshes, resulting from modifications in the upstream system or river stream regulation, **can significantly impact the conservation of these habitats** (Keddy, 2010, Taylor et al., 2021). Marsh plants are specifically adapted to frequent flooding and substantial variations in water levels (Keddy, 2010).

A drier environment may favour swamp species (see **Figure 3.10**), potentially diminishing the marsh's extent, **overshadowing** certain areas, and **diminishing or isolating breeding sites** for amphibians and dragonflies (refer to **3.4.3**). Conversely, a wetter environment characterised by a **stable, higher water level,** possibly leading to the formation of a water body, **could result in the decline of marsh species** (Keddy, 2010; Taylor et al., 2021).

3.4.2.2 What to do?

For small marshes, **minor interventions in regulating the water level** can often be effective in establishing a flooding regime that is suitable for marsh plants (Taylor et al., 2021).

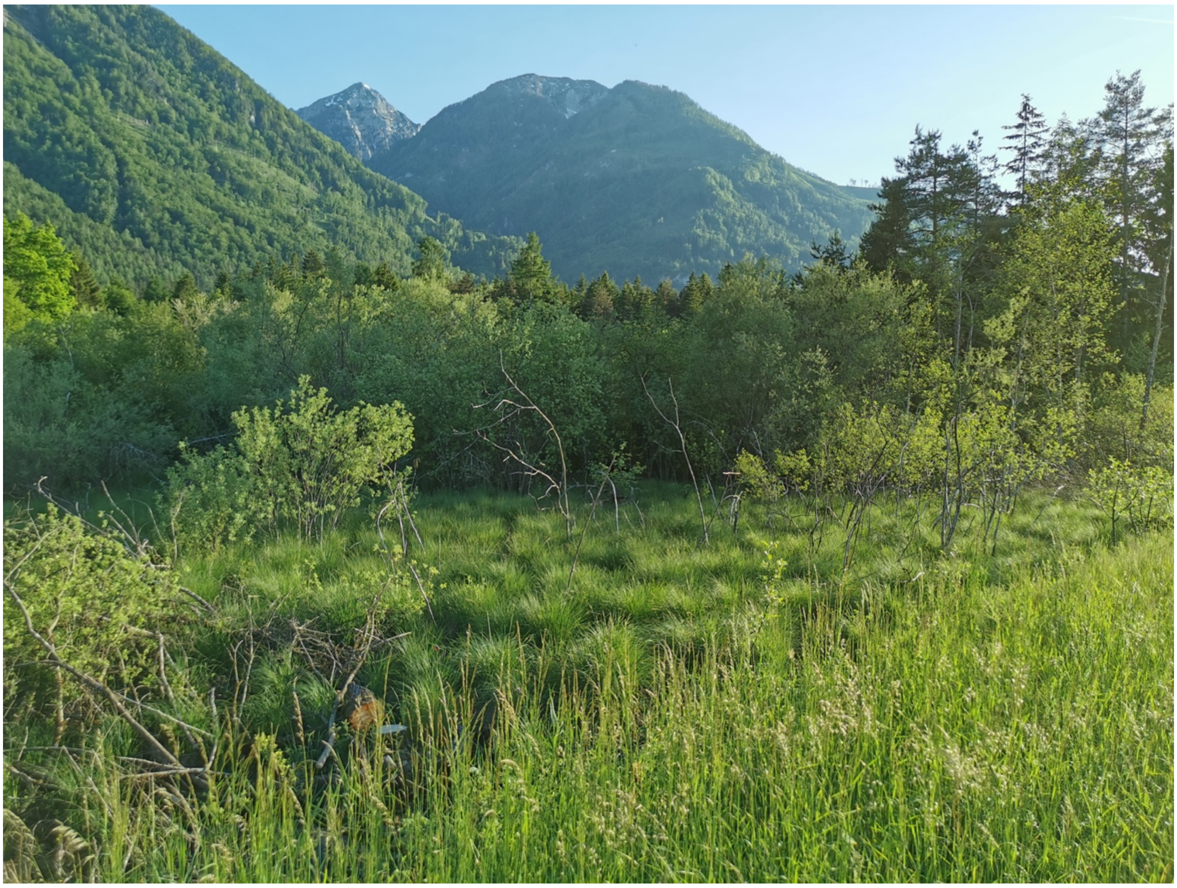

Figure 3.10: A reduced water level can favour the expansion of trees and shrubs (Galizien, Austria, photo: S. Glatz-jorde)

3.4.2.3 Problems

If the water level in marshes is under the regulation of landowners or authorities, it is crucial to **inform these stakeholders** about the significance of these habitats and the necessity for proper water level management. **Significant historical alterations in hydromorphology may require more intensive and costly interventions** to restore a natural flooding regime (Taylor et al., 2021).

In cases where water level regulation is impractical, and the water level is consistently low, you should **consider creating breeding ponds for amphibians and dragonflies** by excavating new ones.

3.4.3 Tree or shrub overgrowth

3.4.3.1 What to expect?

In certain situations, particularly **when dry conditions are common**, marshes may face issues with the **overgrowth of trees and shrubs** (see **Figure 3.10**). Various species of trees and bushes, including *Frangula alnus*, *Alnus glutinosa*, and others, can form **dense stands**, casting shade over large portions of the marsh and **isolating it from adjacent open habitats** like pastures and wetlands.

3.4.3.2 What to do?

You should cut tree and bushes: this helps in maintaining open habitats and establishing corridors towards pastures or other wetland areas, ensuring the connectivity of dragonfly populations (Bonometto, 2020). It's important to note that these tree and shrub species thrive in reduced water levels, so addressing this problem concurrently is recommended (refer to section 3.4.2) (Keddy, 2010; Taylor et al., 2021). **Remember that a clear cut is not necessary.**

3.4.3.3 Problems

If the majority of the marsh site is overgrown, it is advisable to **prioritise the maintenance of the most preserved parts** through periodic cutting. Additionally, efforts should be made to maintain connectivity between these preserved areas.

3.4.4 Invasive plant species

3.4.4.1 What to expect?

Invasive plants can pose a threat to marshes, especially in the sites that are already experiencing other pressures, such as low water level (Taylor et al., 2021).
Refer to sections **3.2.4.1**, **3.3.3.1**.

3.4.4.2 What to do?

See **3.2.4.2**.

3.4.4.3 Problems

See **3.2.4.3**.

3.5 Wet meadows

3.5.1 Introduction

Wet meadows are often found in **poorly drained areas**, including shallow lake basins, wet depressions, along slow-moving streams, and in sloughs with impeded drainage along rivers (Keddy, 2010). They can also be present in low-lying farmland and in the land between shallow marshes and upland areas. Some wet meadows are located at higher elevations in mountainous regions with poorly drained mineral soil. These grassland-like ecosystems, while typically drier than marshes for most of the year, maintain **a high water table that keeps the soil somewhat saturated** (Keddy, 2010).

Wet meadows host a **diverse array of vegetation**, including various grasses, sedges, rushes, and wetland wildflowers. Despite being without standing water for most of the year, the high water table allows the soil to stay moist. These environments support abundant insect life, especially plants and butterflies, making wet meadows important for biodiversity.

During periods of high rainfall, wet meadows collect runoff, reducing the risk of seasonal flooding in downstream low-lying areas. The vegetation in wet meadows acts as a natural filter, removing excess nutrients from the water. This nutrient-rich setting provides essential food and habitats for insects, amphibians, reptiles, birds, and mammals.

Historically, **wet meadows have been subjected to draining and filling for agricultural purposes**, particularly in areas where farming is prevalent. Recognising the ecological significance of these wetlands, conservation efforts are underway to prevent further losses. To maintain their characteristics, wet meadows **often require management practices such as grazing or mowing** to prevent the establishment of woody plants and succession to shrubs or woodland.

Certain types of wet meadows are designated as habitats of community interest, such as *Molinia* meadows (6410), which is discussed in more detail in this chapter (see **3.5.2**).

3.5.2 *Molinia* meadows

In ***Molinia* meadows**, it is crucial to gather comprehensive information about the vegetation, focusing on the presence of invasive or rare/endangered species. These meadows should exhibit **high species richness**: apart from the dominant *Molinia caerulea*, various rushes and sedges contribute to the plant diversity. The specific plants may vary depending on soil conditions and regional factors. Notable species include the common devil's-bit scabious (*Succisa pratensis*), meadow knapweed (*Sanguisorba officinalis*), betony (*Betonica officinalis*), and gentians such as the lung gentian (*Gentiana pneumonanthe*) or the swallow-wort gentian (*Gentiana asclepiadea*).

Molina meadows play a vital role in supporting **diverse insect species** due to their abundance of flowers. Rare butterfly species like the marsh fritillary (*Euphydryas aurinia*), large fritillary (*Lycaena dispar*), dark meadow blue (*Maculinea nausithous*), and light meadow blue (*Phengaris teleius*), along with grasshoppers and spiders, find essential habitats in these meadows.

To assess the health and maintenance of *Molinia* meadows, it is important to **investigate if they are still subjected to regular mowing**, typically once a year, and whether the water level remains stable. Additionally, **evaluating the connectivity** of the meadow with other wetland sites, its position within a network of wetland habitats, potential overshadowing or overgrowth by bushes or *Phragmites*, and any use by cattle or other livestock are essential considerations.

3.5.3 Lack of management / succession to shrubs or woodland

3.5.3.1 What to expect?

The expansion of forested areas over time, often **resulting from natural ecological successions or land-use changes** such as the abandonment of pastures or hay meadows, can **overshadow** wet meadows and reduce their surface (Phillips-Mao et al., 2017). While not necessarily problematic, this process can lead to several issues, including a **reduction in food sources for certain species, landscape homogenization, and isolation** of animal populations (see **Figure 3.11**).

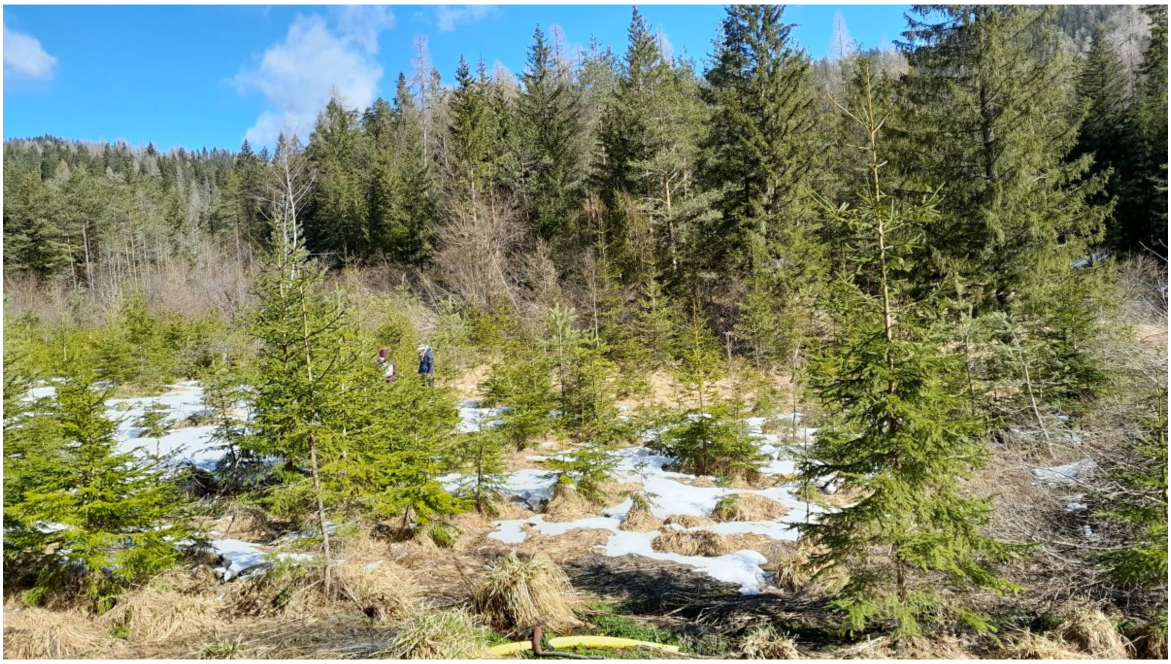

Figure 3.11: over time, wet meadows can suffer from tree or shrub overgrowth, reducing the available habitat for plants and butterflies (Črna na Koroškem, Slovenia)

The **impact on butterfly communities** is noteworthy (Weking et al., 2013), with changes in diversity, composition, and specific abundance depending on the stage of succession. In the initial stages, various ecological niches and structured habitats provide shelter for butterflies in an otherwise open countryside. However, **as shrub overgrowth occurs**, accompanied by a lack of nectar sources, **there is a decline in butterfly abundance**, species diversity, and shifts in community composition.

Regarding *Molinia* meadows that are no longer managed, a distinct structural change is observed, characterized by the development of *Molinia* humps and the dominance of *Molinia caerulea* (see **Figure 3.12**). This results in **reduced vegetation diversity**, and rare species (e.g., orchids) may disappear. The encroachment of bushes and trees such as *Frangula* alnus, *Alnus alnopetula*, *Alnus glutinosa*, various willow species like *Salix cinerea*, and conifers like spruce and pine further contributes to the **overgrowth of the area**. However, it's important to **consider the economic aspects** when dealing with abandoned meadows. The historical use of wet meadows, such as using hay for horse bedding, has diminished due to agricultural mechanisation and changes in farming practices. The traditional activities associated with wet meadow management are now more like museum-like practices for nature conservation, detached from contemporary farming contexts. Additionally, the lack of suitable mowing equipment and the heavy machinery used in modern agriculture pose challenges to the maintenance of these meadows.

Figure 3.12: Degraded and abandoned *Molinia* meadows can often display *Molinia* humps, and a reduction in species richness (Sittersdorf, Austria, photo: S. Glatz-Jorde)

3.5.3.2 What to do?

Adapting agricultural measures to encourage appropriate management of wet meadows and pastures is crucial for preserving butterfly diversity in grassland habitats. In late succession stages, **you should provide open areas and ensure connectivity to other wetlands**: this can help the wetland vegetation regain its initial biodiversity status. You should **minimise the cutting of bushes and trees to what is needed** to connect existing corridors and expand meadow areas.

To maintain the good state of wet meadows, **regular mowing every 2-3 years** in late summer is recommended (Valkó et al., 2012). **If grazed, wet meadows should be grazed with small animals** to prevent excessive trampling.

In the case of *Molinia* meadows, you should organise mowing once a year in late August.

3.5.3.3 Problems

When dealing with privately-owned land, it is advisable to try to **contact the respective landowners** to discuss the historical maintenance activities and potential restoration measures. **Organising pilot measures**, such as using a remote-controlled motor pillar, **can help prepare for further mowing activities** and contribute to the restoration of wet meadows.

If a significant part of the wet meadow is overgrown with shrub, a strategic approach would be to **restore vital sections of it.** This can be done along a transect or at regular distances, giving priority to areas that are easily connected to nearby open areas. Areas occupied by other wetlands or interesting meadows should be especially prioritised in the restoration efforts.

3.5.4 Invasive plant species

3.5.4.1 What to expect?

The abandonment of wet meadows can result in the invasion of non-native species, posing a significant threat to these ecosystems. Invasive species, **especially in areas facing other pressures**, like eutrophication or draining, can outcompete local plants and form extensive stands. The introduction of invasive species can occur accidentally or deliberately, and certain activities, such as **dumping compost in wet meadows** or streams, can facilitate their dispersal. It's crucial to **exercise caution during restoration** work, as invasive species can be inadvertently transported to the site using heavy machinery or other tools.

In some regions, examples of invasive species in *Molinia* meadows include *Solidago canadensis* and *Solidago gigantea*. *Rudbeckia* sp. may also be present, depending on the neighbouring land use. Without proper maintenance, **invasive plants can exploit molehills and overgrow valuable habitats**. It is essential to implement effective measures to control and manage invasive species during wet meadow restoration.

3.5.4.2 What to do?

See **3.2.4.2**. Keep in mind that i**nvasive species can succeed in wet meadows that suffer from other pressures**: your efforts should address these factors too.

3.5.4.3 Problems

If a wet meadow is dominated by a few rapidly growing species, it is important to **consider reducing those populations**. This can be achieved **by cutting the dominant**

species at the end of the dry season using lightweight equipment and ensuring the removal of clippings. You should **avoid mowing more than a quarter of the habitat** to maintain a diverse ecosystem. Some species, such as *Solidago gigantea*, require more intensive management, and additional measures may be necessary. Refer to section **3.2.4.3**.

3.5.5 Excessive livestock trampling and eutrophication

3.5.5.1 What to expect?

Trampling, herbivory, and eutrophication can pose significant challenges to wet meadows. In the case of ***Molinia* meadows pastured by livestock**, the dominance of *Deschampsia cespitosa* and a few other species can lead to the overtaking of the original *Molinia* vegetation. This process, coupled with **eutrophication**, may result in the local extinction of *Molinia caerulea* and numerous other plant species.

3.5.5.2 What to do?

In this case, **you should exclude livestock by using electric fences**, as described in section **3.2.2.2**: this can help prevent trampling and overgrazing. The fencing can be applied to the entire wet meadow or specific access points. **If water sources are not available** within the meadow, **fencing without electrification can also be considered**.

For effective long-term management, **mowing the meadow at least once a year is highly advised**, focusing on controlling *Deschampsia cespitosa*. The mowing operation should take place at the end of the season, utilising lightweight equipment. Ensure proper collection and removal of clippings, relocating them outside and downstream of the wet meadow.

3.5.5.3 Problems

Tussocks of *Deschampsia cespitosa* **can be quite hard** to mow and are resistant. Make sure to **use brush cutters, mounting blades,** or a small **sickle mower**.
If *D. cespitosa* is not present, you should **consider lighter equipment**, such as string trimmers.

3.6 Swamps

3.6.1 Introduction

Swamps are habitats dominated by trees, typically waterlogged or flooded for short periods throughout the year (Keddy, 2010; Taylor et al., 2021). Some examples can be floodplains or riparian forests in the valley floors, that are often inundated. These are, as a rule, young development stage forests, overgrowing gravel bars from the banks of the rivers up towards higher and older river terraces. From very unstable initial stages (willow scrubs on gravel bars), development proceeds through stands of grey alder and ash to established communities, which are still under the influence of groundwater or floodwater. **The survival of these forests is therefore determined by standing or running waters**, or the community develops only under the direct influence of the watercourse (Keddy, 2010; Taylor et al., 2021).

Forests of this habitat type are endangered, as human influence on them is very large, namely in the form of **cutting, drying, regulation of watercourses, construction of dams, construction of cities and infrastructure and agriculture**, and indirect due to climate change (droughts, shortened duration of floods) (Taylor et al., 2021). The consequences of the above can also be the **fragmentation of these forests and soil pollution of growing areas with pesticides and fertilisers that are washed away with water**, the disorders of rejuvenation of all of key tree species, diseases of forest trees and the invasion of invasive alien plant species (Taylor et al., 2021).

3.6.2 Hydromorphological changes

3.6.2.1 What to expect?

Due **to hydromorphological changes**, such as the consolidation of river banks, reduced formation of dunes, intense flooding, decreasing groundwater levels, and deepening of the riverbed, as well as excessive water use, there can be a **significant impact on the flooding regime of nearby areas**, particularly for marshes and swamps (Taylor et al., 2021).

An excess of water can damage trees and slow their natural rejuvenation, gradually leading to the **formation of marshy habitats dominated by grass-like vegetation** that is more adapted to long periods of flooding and disturbance caused by waves or ice (Keddy, 2010; Taylor et al., 2021). On the other hand, a **lack of water can facilitate the dominance of tree species adapted to drier environments** (Keddy, 2010; Taylor et al., 2021).

In swamps, these conditions are clearly manifested through the **loss of key tree species and/or the absence of natural rejuvenation** of communities. The deteriorated conditions are further exacerbated by invasive nonindigenous plant species, which hinder the rejuvenation of this forest habitat type.

3.6.2.2 What to do?

The crucial step in in this case is to **restore the original flooding regime**. Often, particularly when the primary cause is the alteration of river banks or river stream regulation, **comprehensive renaturalisation efforts are needed** (Taylor et al., 2021). While these interventions can be expensive and intensive, they are essential for restoring the natural balance. In some instances, smaller-scale interventions, such as **improved stream regulation or reduced water use upstream**, may yield benefits (Taylor et al., 2021).

To enhance the condition of floodplain forests or valley floor swamps, efforts should also focus on **restoring tree stands** (Taylor et al., 2021). This can be achieved by **planting indigenous, locally-characteristic tree species**, providing active support for natural rejuvenation processes.

3.6.2.3 Problems

When degraded swamps are affected by **pests like bark beetles**, it's important to **consult regional or national protocols** for the management of such species.

3.6.3 Invasive plant species

3.6.3.1 What to expect?

In degraded swamps where **characteristic trees are facing challenges such as a reduction in the water table,** modifications to the flooding regime, or the presence of parasites, the **formation of gaps** in the vegetation **can create opportunities for invasive species** (Taylor et al., 2021). These invasive species may exploit the disturbed areas, hindering or **slowing down the natural rejuvenation** of characteristic swamp species.

3.6.3.2 What to do?

See **3.2.4.2**. Keep in mind that i**nvasive species can succeed in swamps that suffer from other pressures**: your efforts should address these factors too (Taylor et al., 2021).

3.6.3.3 Problems

Refer to sections **3.2.4.3**, **3.5.4.3**.

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