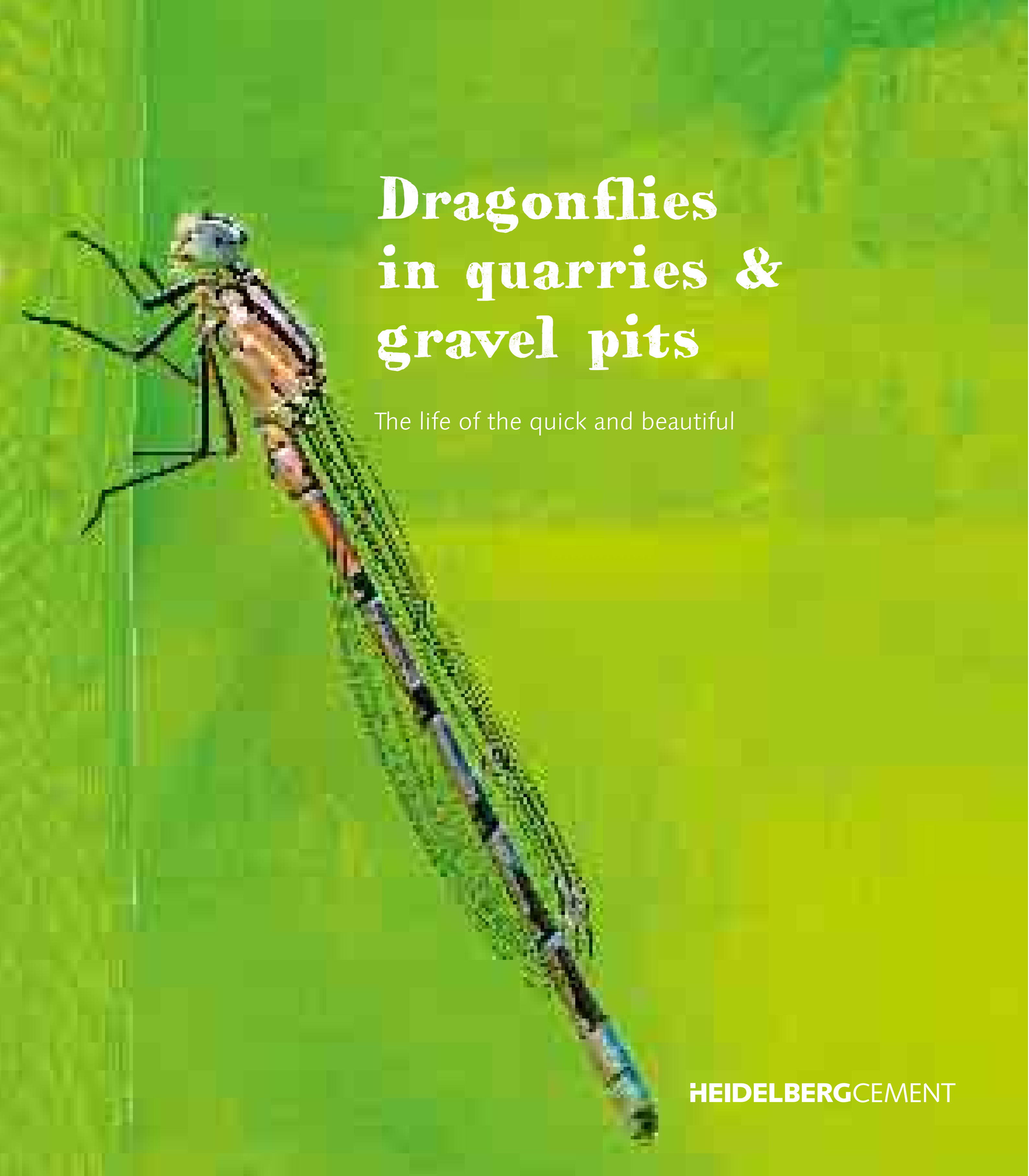

Dragonflies in quarries & gravel pits

The life of the quick and beautiful

HEIDELBERGCEMENT

Dragonflies in quarries & gravel pits

The life of the quick and beautiful

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Table of contents

Preface

Quarries and gravel pits are secondary habitats. They supply the non-metallic mineral processing industry with raw materials and are the basis of many everyday goods. It is little known, however, that mineral extraction sites can be invaluable habitats for many plant and animal species. Quarries and gravel pits can be important retreats for many rare and threatened species – not only after quarrying is completed, but also while it is still underway. The importance of steep rock or sand faces for the eagle owl (*Bubo bubo*), the peregrine falcon (*Falco peregrinus*) or the sand martin (*Riparia riparia*) is common knowledge. The little ringed plover (*Charadrius dubius*) has become generally rare, but it is a common breeder on the open gravel plains of our gravel pits and a dear sight to many nature lovers.

Beyond these conspicuous animals, the species richness of our mineral extraction sites is recognisable for specialists only. The barren appeal of mineral extraction sites does not attract many citizen naturalists, and in addition all active quarries and gravel pits are not freely accessible for safety reasons. For these reasons the widespread perception is that quarries and gravel pits are open wounds of the landscape rather than potentially important habitats for threatened plants and animals.

The HeidelbergCement Company is one of the leading suppliers of heavy building materials worldwide. Sustainable use is a crucial element of corporate activity. Protection of plants and animals is one important contribution to it. The quarrying of limestone, sand, and gravel only take place where geological prerequisites, markets, and logistics are favourable. Neither arbitrary openings of new mineral extraction sites nor the displacement of existing mineral extraction sites are undertaken. This practice can be advantageous for the protection of biodiversity, however: Extraction sites are active over many decades and offer space and time for thoroughly planned, targeted opportunities for the protection of nature. HeidelbergCement has a long history of projects aiming at the protection of biodiversity. In many cases, these projects are planned and set into action in cooperation with nature protection organisations, governmental agencies, and universities. In 2008, the company has established guidelines for the promotion of biodiversity in the mineral extraction sites, which is required for all production sites. The guidelines define concise, measurable targets and present indicators for monitoring success. In the future, plans for nature management will be set up for all mineral extraction sites in regions with high biodiversity. These plans will help the people in charge of our quarries and gravel pits to implement concrete actions in favour of regionally threatened plant and animal species or even complete biotopes.

Mineral extraction sites are characterised by a multitude of different habitats for an array of specialised species. This book about dragonflies, a stunningly beautiful and interesting animal group, is the first in a series of books presenting characteristic habitats of our mineral extraction sites. Dragonflies, just like amphibians, spend an important phase of their life cycle in water. Each species prefers a specific type of aquatic habitat. Such specificity qualifies dragonflies as important environmental indicators. It may sound surprising that not only gravel pits but quarries as well may harbour diverse aquatic habitats which are of great importance for highly specialised pioneer species. This book is intended to give an entertaining insight into the fascinating world of dragonflies and to inform about waters in mineral extraction sites as habitats. We hope you enjoy the reading!

Dr. Michael Rademacher,
Global Manager Biodiversity & Natural Resources,
HeidelbergCement

Greetings

Biological diversity and landscape dynamics form an entity. This is also true for dragonflies and their habitats. Klaus Sternberg and Rainer Buchwald, in their books about dragonflies published in 1999 and 2000, identified flood plains with their inherent dynamics as natural habitats of many dragonfly species. In our human-made cultural landscape, many landscape components have lost their naturalness and dynamics. They are either fixed by agricultural or forestry use or by infrastructure, or nature itself preserves them in a conservatory way in a state defined as optimal by humans.
Aboveground mining creates landscapes which contain elements of natural landscape dynamics for a certain period of time. Therefore, many organisms, including dragonflies, colonise such human-made habitats. In many cases, these species are classified as rare, threatened habitat specialists or pioneer species. Technical progress and profit maximisation have led to an ongoing decrease in mining landscapes with optimal structures. Above all, rapid backfilling following exploitation has shortened the availability of potential habitats for dragonflies and other organisms.

On the other hand, responsible companies whose activities have a strong impact on the landscape recognise that they have to contribute to the preservation of biological diversity.

This book, issued by the globally acting mining company HeidelbergCement, presents active and post-use mineral extraction sites as human-made habitats and places of biodiversity. They are used as habitats by many organisms including dragonflies.

In this sense, the book is a plea for an alliance between human land-use and the creation of habitats for many species that depend on dynamic landscapes. More than six hundred persons from several European countries who are members of the association of German-speaking odonatologists get involved with the protection and preservation of dragonfly habitats. Representing them, I hope that this book will be widely read. If it contributes to the mutual understanding of conservationists and landscape users and is utilised by companies as a guideline for the creation and perpetuation of biotopes which have become rare, it has achieved two important goals.

Dr. Thomas Brockhaus,
Chairman of the Society of German-speaking Odonatologist (GdO e.V.)
www.libellula.org

The life
of the quick and beautiful

01

01 The small bluetail (*Ischnura pumilio*) feeding on a cicada.

02 Dragonflies are racy airborne predators – a male blue-eyed hawker (*Aeshna affinis*) is hunting in the reed zone.

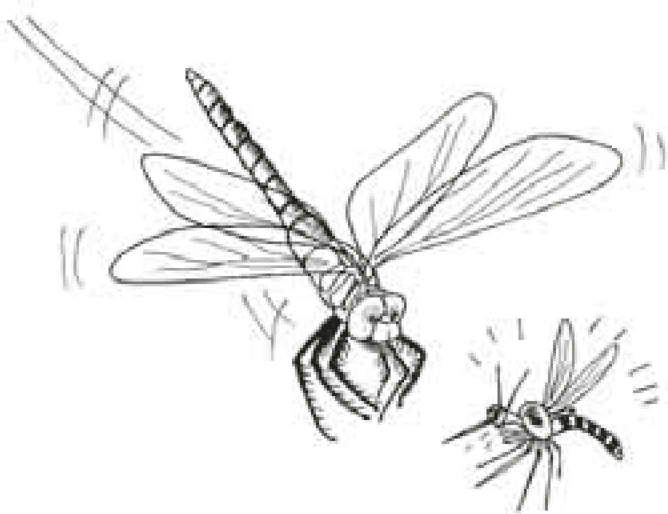
02

Predators, fast as lightning...

Dragonflies are among the oldest insects on Earth. Their ancestors already were buzzing through bog forests of the Paleozoic, 300 million years ago.

As airborne predators they are perfectly adapted to hunting in flight. Their wings are powered and controlled by massive muscles, allowing for spectacular flight manoeuvres. Dragonflies are capable of hovering like miniature helicopters, and they are the only insects that can fly backwards.

The diet of dragonflies consists mainly of other insects, among them many obnoxious bugs such as gnats, blackflies, or horse flies. The legs of dragonflies, very sturdy and equipped with small spines, can be used as "trap baskets". After a prey gets "netted" in a thorny embrace, the dragonfly settles on a twig or leaf to devour its meal. Note: All dragonflies are completely harmless for humans – no stings, no bites, no poison!

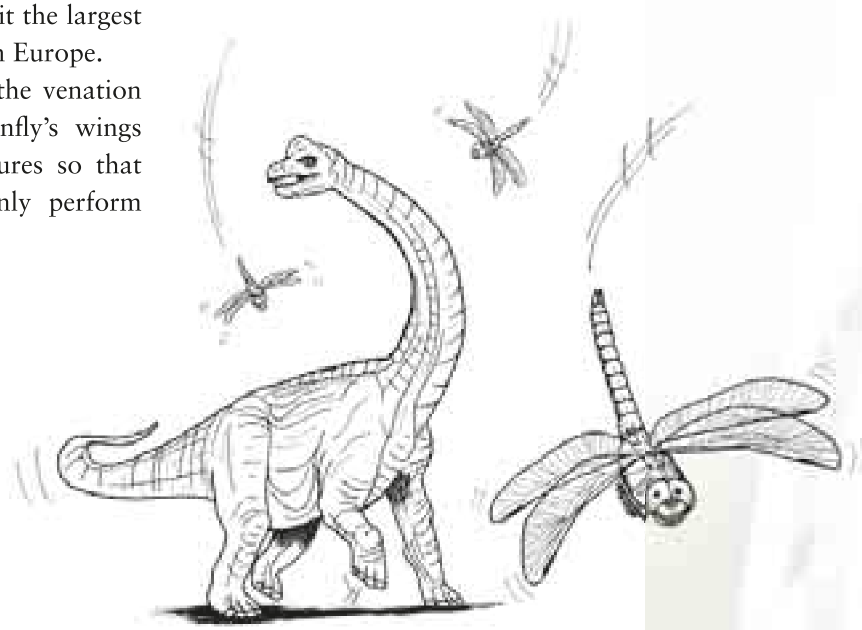


Dragonflies in primeval times

The ancestors of our dragonflies (Odonata), the “archetype dragonflies” (Protodonata), have survived as fossils. They lived in the Mississipian – a subperiod of the Carboniferous Period – about 325 million years ago and could reach amazing sizes. In 1885, a fossil of the archetype dragonfly with the scientific name Meganeura monyi Brogniart was found at Commentry in southeastern France. Its wings spanned 67 cm, making it the largest fossil insect ever found in Europe.
Some fossils show that the venation of the archetype dragonfly’s wings lacked stabilising structures so that they could probably only perform short gliding flights.

Dragonfly fossils from the Late Triassic (ca. 200 million years ago) already have a strong resemblance with dragonfly types of today.

In other words: When the dinosaurs went extinct about 65 million years ago, the dragonflies had already seen about 135 million springs – and in contrast to the dinosaurs they are still around today!



01 The hairy hawker (*Brachytron pratense*) has huge high-performance eyes, just like all dragonflies.

Dragonfly records

Dragonflies are master pilots and flying acrobats. Their powerful flight muscles allow them to accelerate from 0 to 15 km/h in 1/3 s and to reach top speeds of up to 40 km/h. They can switch from horizontal to vertical flight in an instant without having to slow down a lot. They can slam on the brakes, stop abruptly, and hover stationary. For such flight manoeuvres, perfect vision is needed. Dragonflies can spot their conspecifics from distances of more than 20 m. But above all, with up to 300 images per second, dragonfly eyes have a fivefold quicker visual resolution than the human eye. Moreover, dragonflies can perceive polarised light.

Some migratory dragonfly species cover the longest distances within the entire kingdom of insects. Over the course of one year, the wandering glider (*Pantala flavescens*), in four to five generations, flies from India via Sri Lanka, the Maledives, the Seychelles to East Africa and back. The total distance is about 16,000 km.

The largest European dragonflies are the goldenrings (*Cordulegasteridae*) with a body length of up to 96 mm. The smallest dragonfly in Europe is the sedling (*Nehalennia speciosa*), which measures only 26 mm.

01 The blue hawker (*Aeshna cyanea*) hovers just like a helicopter.

02 A male blue hawker (*Aeshna cyanea*) on its flight patrol.

02

Bionics is an interdisciplinary science combining technology and natural sciences. Biologists, physicists and engineers, designers and IT specialists cooperate in order to translate ingenious inventions of nature into technical products.

Leonardo da Vinci, who studied the flight of birds for his flight apparatus, is considered the first to employ bionics. Other famed applications are the "lotus effect" – surface structures of the Lotus plant were imitated in order to achieve a water and dirt repellent effect – and velcro, the fabric version of a principle found in burrs attached to an animal's fur. Helicopters are inspired by dragonflies, but the dragonfly flight is superior by far.

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01 An red female broad-bodied chaser (*Libellula depressa*) – to be identified by its flat, broad abdomen – with unusual coloration.

02 Portrait of the common darter (*Sympetrum striolatum*).

03 Males of the large redeye (*Erythromma najas*) are characterised by their ruby red eyes.

Glistening artists in flight

03

So far we have only been talking of dragonflies. In fact, however, there are two groups of dragonflies: true dragonflies and damselflies. True dragonflies are conspicuous owing to their body size and rapid flight. When resting, their wings spread in a more or less horizontal position.

Damselflies are smaller and more delicate; their flight style is less steady. When resting, wings are folded together on top of their abdomen.

The head of true dragonflies and damselflies is highly mobile and dominated by huge compound eyes which allow nearly a complete panoramic view. The compound eyes of damselflies may consist of up to 14,000, those of the largest dragonfly species of up to 60,000 individual eyes. The hectagonal corneas form a honeycomblike surface of the eye. The wings are finely nerved, and the venation is different in every species. A typical structure of a dragonfly wing is the conspicuous pterostigma, a small coloured region near the wingtip. Its function is not yet fully understood. It may play a role in aerodynamics by preventing uncontrollable wing fluttering, i.e., self-exciting vibrations of the wings.

Differences between dragonflies and damselflies

True Dragonflies (Anisoptera)	**Damselflies** (Zygoptera)
Body large, sturdy	Body smaller, always slender
Fast and longlasting flights	Slow, fluttering flights
Wings spread more or less horizontally while perching	Wings folded together on top of abdomen
Hindwings wider than forewings	Fore- and hindwings almost identical
Eyes very large, touching each other on top of the head. Exception: clubtail dragonflies (Gomphids)	Eyes on the sides of the head, never touching each other
Larvae with “caudal pyramid”	Larvae with external, leaflike anal gills at the tip of the abdomen

01 The blue-eyed hawker (*Aeshna affinis*) has a characteristic colour pattern on its abdomen and luminous blue eyes.

02 The small spreadwing (*Lestes virens*) – the photo shows a male – is a very delicate damselfly species.

03 The banded demoiselle (*Calopteryx splendens*) is one of the largest and most beautiful damselflies.

02

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Dragonflies are among the largest and most colourful insects. The often intense co-louration of the body, more seldom of the wings as well, is species specific and very appealing. This colouration is why dragonflies are often referred to as “flying jewels”.

Juvenile times in water

Every dragonfly's life begins as a larva in water. The larvae look so different that most people would not even recognise them as dragonflies. The tip of the abdomen of damselflies bears leaflike external anal gills, whereas dragonflies carry pointy spines, the so-called "caudal pyramid". Even the dragonfly larvae are something special: They are the only insects equipped with a "prementum". This structure lies below the larvae's mouth and has sharp hooks designed to hold onto a prey. It can be hurled forward almost like a harpoon. The larvae of some species lurk hidden in the sediment, others rest among water plants, preying on gnat larvae, worms, small crustacean, and other small water animals.

In order to grow, the dragonfly has to moult up to 16 times. In contrast to butterflies, there is no pupal stage. At the end of the larval phase, which may last from several weeks to a few years depending on species, the final moulting and metamorphosis takes place. Inside the larval skin, ready to crack open, is the dragonfly, complete with wings and all in a compressed form. Upon leaving the water, the larva clings to a suitable small stem or blade of grass in the shore vegetation. The larval skin splits open and the winged insect emerges. In order to reach its final size and shape, the dragonfly inflates itself with air and body fluid. It takes some time for the wings to harden enough so the dragonfly can take off on its maiden flight. The colours of the juvenile dragonfly are dull at first. It takes several days until the brilliant colours are fully developed. Exuviae are species-specific, and specialists can determine by them which species reproduced in a given body of water.

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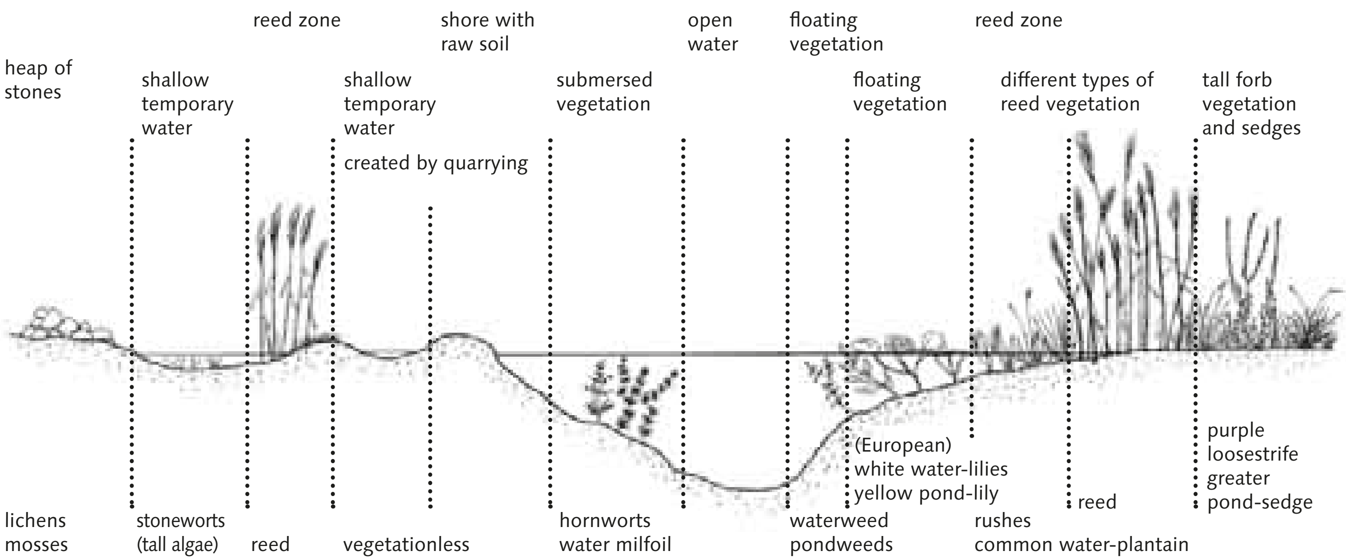
01 A typical larva of a true dragonfly: the yellow-winged darter (*Sympetrum flaveolum*).

02 A typical larva of a damselfly: the blue-eye (*Erythromma lindenii*).

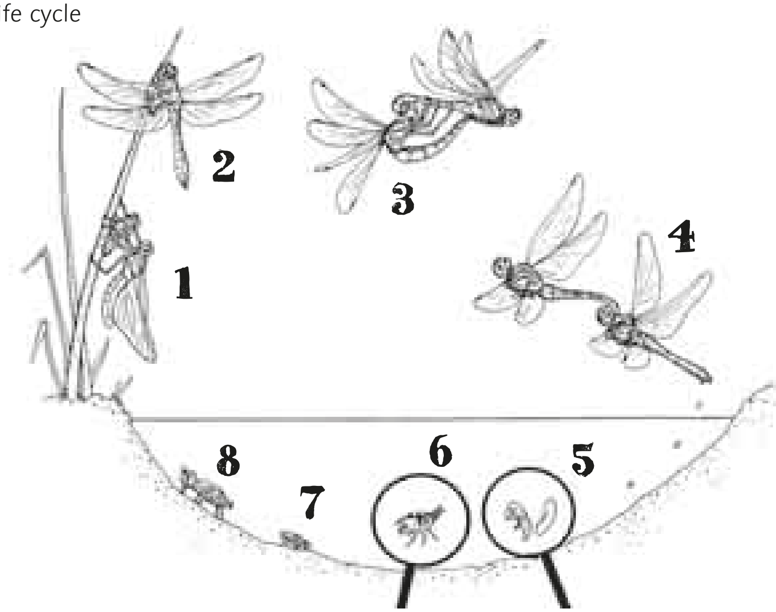
03 A downy emerald (*Cordulia aenea*) has emerged from its larval skin.

04 The larval skin (*exuvia*) – in this case of a hawker – is left behind in the vegetation.

Scheme of a shallow pond and its shore zone

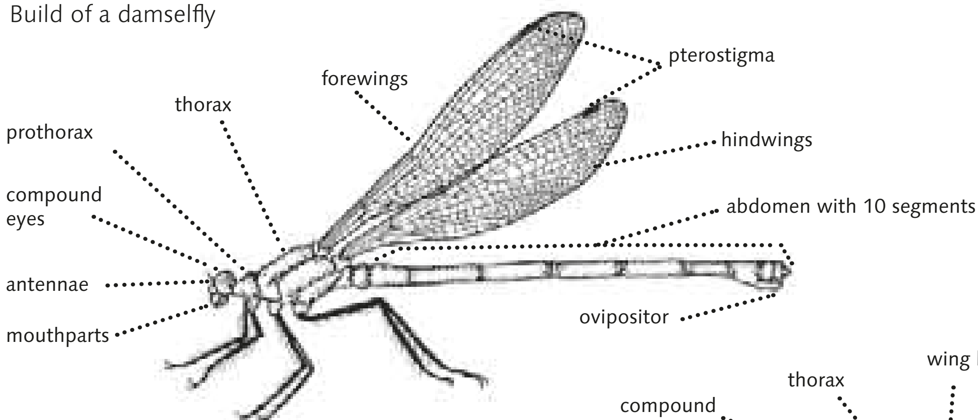


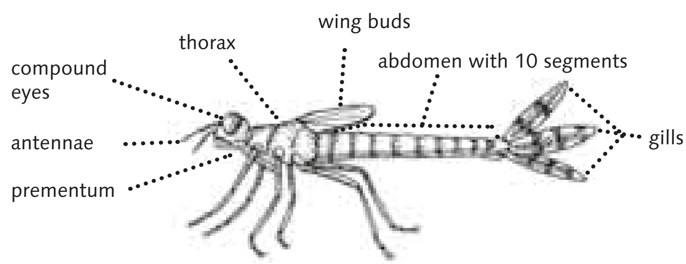
Life cycle



1. The imagoe emerges from its larval skin (*exuvia*)
2. Hardening of the wings and maiden flight
3. Search for mates and mating
4. Egglaying (*oviposition*)
5. The prolarva hatches from its egg
6. Moulting and transformation to the actual larva
7. Growth and multiple moultings
8. Final-instar larva ready to leave the water

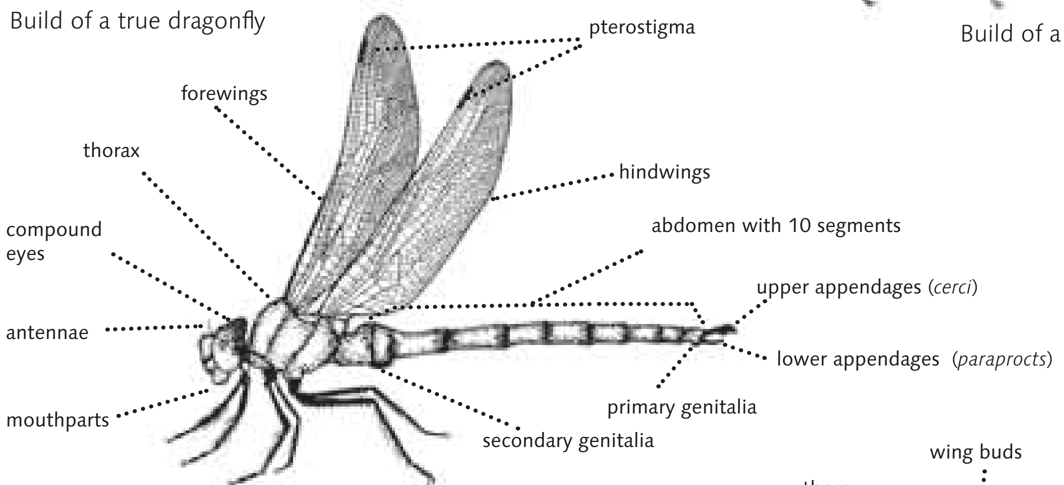
Build of a damselfly

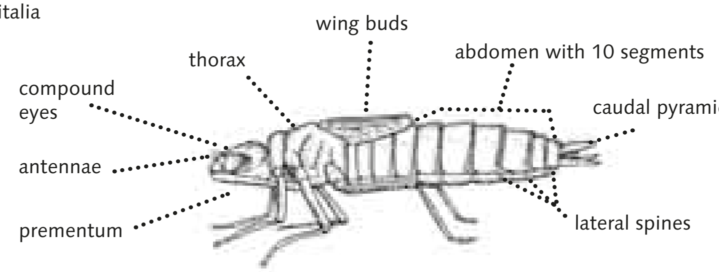




Build of a damselfly larva

Build of a true dragonfly





Build of a true dragonfly larva

The life span of an adult dragonfly ranges from a few weeks to two to three months. Exceptions are the two species of winter damselflies, the only European dragonflies that overwinter as full insects. All others endure winter in the larval or the egg stage.

Dragonflies spend their time hunting for insect prey and with reproductive activities.

The landscape around water bodies, land habitat, plays important roles: chiefly as hunting grounds but also as sleeping and rendezvous sites. Some dragonflies may switch between land habitats and breeding waters several times a day, covering several kilometres. The more variable the mosaic of habitats, e.g., waters, forest edges, grassy vegetation, the better the life conditions for dragonflies.

01 Dragonflies profit from a mosaic of different habitats. This photo shows a pond with shore zone, shrubs, trees, and open soils.

02 A pair of common winter damsels (*Sympecma fusca*) – the only "hardy" dragonfly.

Holometabolism (complete metamorphosis) and hemimetabolism (incomplete metamorphosis)

In insects, we differentiate between holometabolism (complete metamorphosis) and hemimetabolism (incomplete metamorphosis).

In holometabolic insects, appearance and life style of larvae and adults (also called imagoes) differ strongly. The transition between larval and adult phase is characterised by the pupal stage during which the animal transforms itself into something completely different. During this time, no food is taken up, and in most insects groups no activities are observed. Among others, bees, butterflies, and beetles belong into this group.

Hemimetabolic insects do not have a pupal stage. Instead, the larva becomes more and more similar to the adult with each moult. This change is best observed by increase in body size and in the length of wing buds. The final larval moult marks the metamorphosis to the adult insect. Dragonflies, grasshoppers, mayflies, and cicadas are characterised by incomplete metamorphosis.

01 Wheel of the black darter (*Sympetrum danae*).

02 Wheel of the common bluetail (*Ischnura elegans*).

03 Tandem of the red-veined darter (*Sympetrum fonscolombii*) laying eggs.

Dragonfly love

03

The way dragonflies mate is unique among insects: They form the so called “wheel” that allows them to remain mobile while mating so they can escape from enemies. The male dragonfly grasps the neck of the female with little “tweezers” at its abdominal tip. The female then bends up its abdomen, linking its tip with the secondary genitalia that are located in the front part of the male’s abdomen in order to receive sperm. The male must have filled this organ beforehand by bending forward its abdominal tip where the sperm are being produced. Once the wheel is formed, specialised structures, barbed hooks and bristles on the secondary genitalia, are used to remove the sperm of other males, which have mated with the female before. The females store the sperm, and it is used for fertilisation in the very moment of egg laying. Depending on the species, eggs are either laid in plant tissue or other substrates using an ovipositor or dropped right into the water whilst hovering above the surface. Under favourable conditions, larvae can hatch from the eggs and the life cycle begins anew.

Sperm competition and female guarding

Sperm competition refers not only to competition between individual sperm from one male, but also between sperm from different males. In dragonflies the last male that mates with a female has the best chances to propagate its genes. The sexual organs of dragonflies fit together according to the lock-and-key-principle, and the male is capable of scooping out the sperm of its predecessor(s) with its sophisticated secondary genitalia. For this reason, males of most dragonfly species **guard their females** during egg deposition either by staying attached to the female's neck and flying about as a tandem (see life cycle) or by staying close to the egglaying female and fending off other males that approach the site.


01

The metapopulation concept helps to study and explain population structures in space and time. A metapopulation is a population of several subpopulations, which are spatially separated but connected to each other by the exchange of individuals.

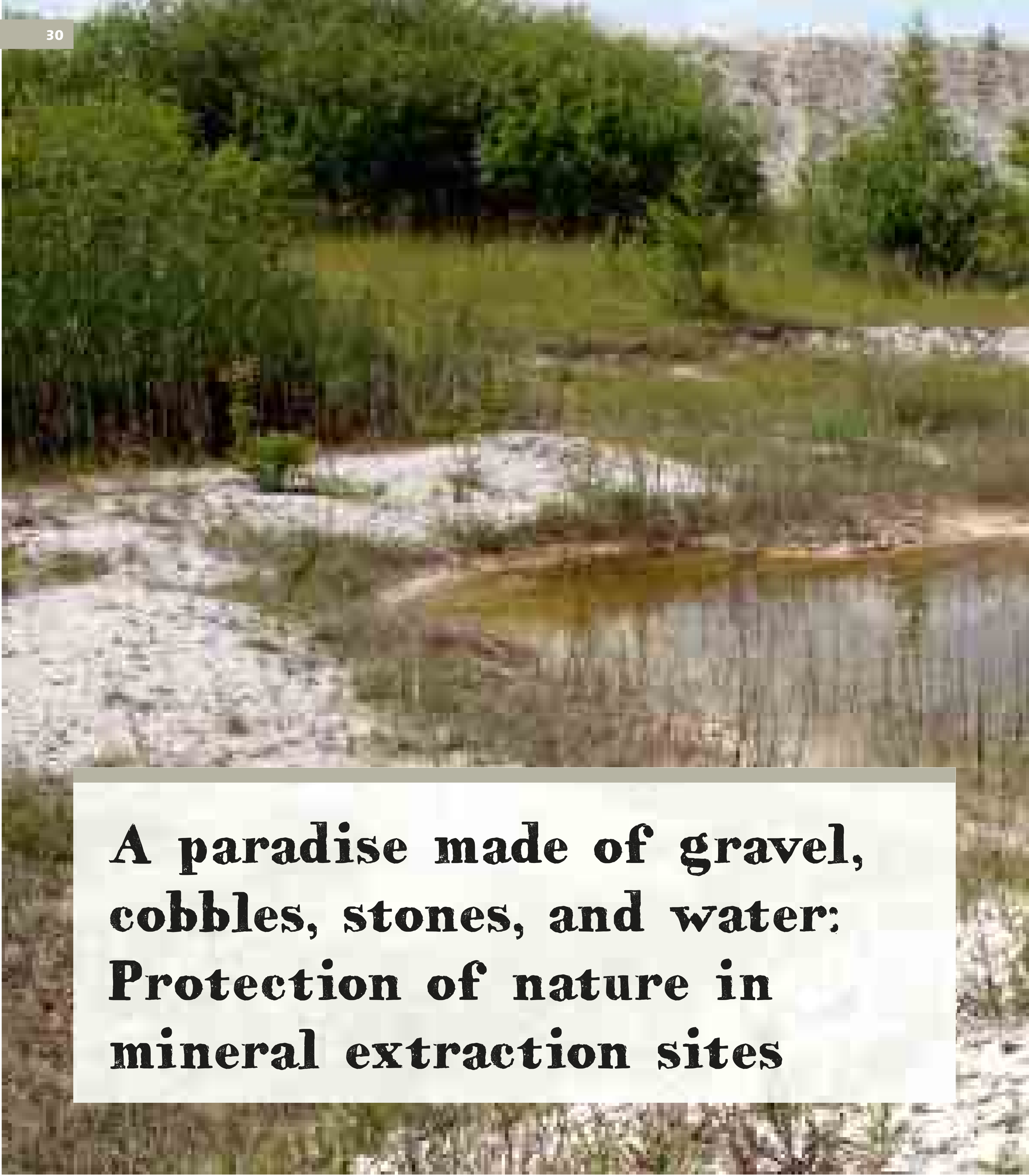
Species with a low potential for dispersal tend to occur in metapopulations. Migratory species, on the other hand, often form homogeneous populations covering vast areas where individuals exchange freely.

The quality of a species' habitat defines the size and stability of a subpopulation developing in it. In optimum habitats, subpopulations thrive so well that overpopulation occurs. Consequently, many animals emigrate, making the subpopulation a centre of dispersal. In less suitable habitats, the long-term survival of a subpopulation may depend on animals immigrating from outside. Some habitats can not be colonised permanently but play an important role as stepping stones, where migrating animals can rest and forage, thereby making it easier for them reach the nearest suitable habitat.

The easier it is for individuals to roam between the subpopulations, the higher the metapopulation's stability and resilience. Habitats where a subpopulation goes extinct following a catastrophic event (for example when a body of water dries up completely) can be recolonised easier, and newly created habitats are more likely to be populated. On the genetic level, migration processes mean gene flow. Gene flow prevents genetic impoverishment of subpopulations, which, in the long run, leads to a high risk of extinction.

A network of currently and formerly used mineral extraction sites, in which a thorough plan of natural resource management is carried out, may play an important role in supporting metapopulations which are large, stable, and fit for long-term survival. Such a network of sites would be especially important in cultural landscapes where land use is intense.

01 Most dragonfly species display sexual dimorphism, i.e., males and females look completely different, as can be seen in this photo of a pair of ruddy darters (*Sympetrum sanguineum*).



A paradise made of gravel, cobbles, stones, and water: Protection of nature in mineral extraction sites

Destruction is followed by new life

The quarrying of raw materials means an irreversible impact to a landscape. Topsoil that developed over milleniums is removed, and plants and animals are expelled or killed. The existing eco-system is forever changed. What remains appears like a barren moonscape, but may develop into habitats for rare and endangered species.

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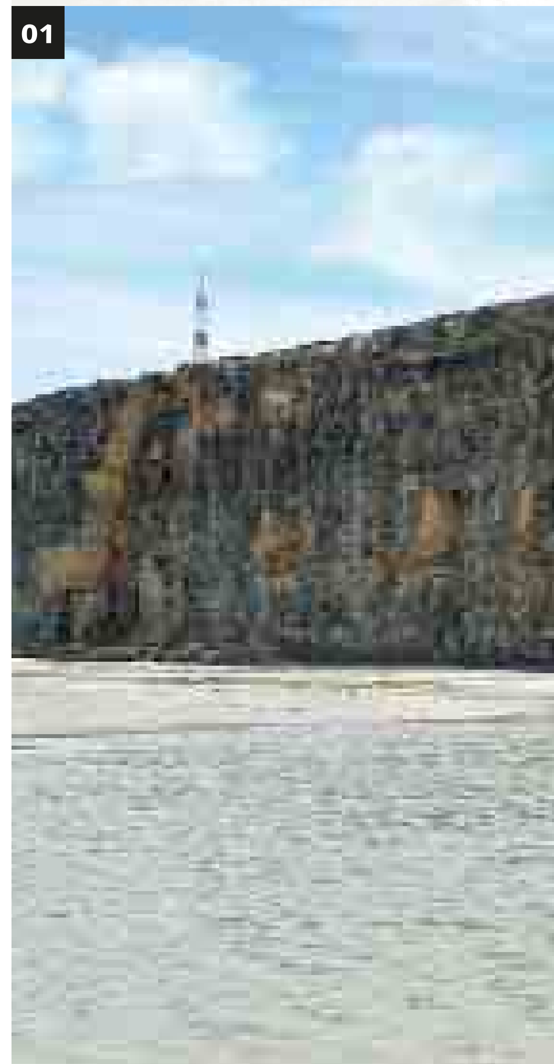

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01 Rock face in a quarry.

02 In some gravel pits the little ringed plover (*Charadrius dubius*) can be observed.

03 Gravel plant with gravel pit lake and conveyors.

01 This ground beetle (*Broscus cephalotes, Carabidae*) prefers bare sandy soil.

02 Bare or only sparsely vegetated soil in shallow inundated shore zones is an important biotope for many specialised plant and animal species.


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03 Body of water in a gravel pit.

04 Wallpepper (*Sedum acre*).

Dynamics in gravel pits

Gravel pits are similar to natural river shores and floodplains, which have disappeared from our “modern landscapes” almost completely due to human activities. Before humans changed rivers and their floodplains, every flood created new biotopes. The powerful water carved into the landscape, eroding gravel and soil in one place, depositing it in another one. Raw soils were exposed or sediments deposited where pioneer species, both plants and animals, found new habitats. When the floods retreated, they left behind newly created ephemeral ponds required by many amphibians, dragonflies, and other animals for reproduction. Today, almost all rivers and streams in Europe are straightened and regulated; shoreline stabilisation, water-retaining structures, and barrages reduce dynamic processes almost to zero. Therefore, many floodplain habitats and their inhabitants are threatened strongly and need to be protected.

Outside the floodplains, natural waters such as marshes, ponds, spring runnels, and in calcareous regions sinkholes as well, were markedly decimated by intense agricultural and forestry use.

01

01 Richness of structures in a quarry.

02 Water bodies develop in almost every mineral extraction site – some are permanent, some temporary.

03 The northern dune tiger beetle (*Cicindela hybrida*).

Temporary waters

Temporary micro-aquatic habitats can be small ponds or pools, sometimes even just waterfilled wheel tracks, which dry up periodically. Species adapted to these extreme habitats are the green toad, the yellowbellied toad or, among the dragonflies, the broadbodied chaser. They all deposit their eggs exclusively in such habitats.

The disadvantage of temporary habitats is the risk that larval development is not completed and they die when the water dries up. The advantage, however, is that the larvae are not preyed upon by fish or most other predators because they cannot survive in these temporary habitats. For this reason, typical dragonfly larvae of temporary habitats have no protection against fish, whereas dragonfly larvae usually occurring in aquatic habitats with fish try to minimise predation with spines on their backs and sides and by a cryptic, slow life style.


01

Pioneer species are plant and animal species that are capable of quickly detecting and colonising newly created habitats. Pioneer plants are the first to appear on raw soils. They produce huge amounts of lightweight seeds that are transported over long distance by wind, or sticky seeds that travel by waterfowl. The seeds of some species are very resistant, buried in the soil, they may remain viable for centuries. Pioneer dragonfly species are among the first to colonise newly created waters. In natural landscapes, the pioneer habitats are created during floods in floodplains, or during catastrophic events such as avalanches and landslides. These habitats are not permanent so that pioneer species depend on their periodic recreation.


02

01 Field cottonrose (*Filago arvensis*), a pioneer species.

02 Panoramic view of a turquoise water body in a mineral extraction site.


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01 Seen from above, the yellow-bellied toad is mud-coloured and well camouflaged.

02 The grey and yellow pattern on the belly of the yellow-bellied toad (*Bombina variegata*) is designed to scare off predators – and warns of the poison it secretes from glands in its skin.

03 Ponds, moist areas, shrubs, and dry gravel banks – all this can ideally be found in a mineral extraction site. In the foreground: blueweed (*Echium vulgare*).

04 Lesser centaury (*Centaurium pulchellum*).

A substitute for natural flood-plains

Today, dynamics comparable to conditions in natural floodplains can only be found in mineral extraction sites in most regions of Europe. Therefore, they can offer important secondary habitats for flora und fauna and in this way contribute to the conservation of biodiversity.

Gravel pits contain vast gravel plains, raw soils, and vegetated areas where numerous insects, amphibians, and birds, as well as pioneer plants such as the lesser centaury (*Centaurium pulchellum*) or the blueweed (*Echium vulgare*), can exist. Steep faces created by quarrying replace bank erosion where sand martins (*Riparia riparia*) can dig their tunnels for nesting.

Ecological conditions in quarries and gravel pits are similar in many regards. However, owing to geological conditions (hard rock), dry habitats, for instance screes, near-natural dry meadows, and dry forests, dominate, whereas wetlands and waters are less abundant and smaller but hardly missing completely. Oftentimes they are filled with water only during humid seasons and dry up in the summer months. These temporary waters are highly important for some specialised amphibians such as the yellow-bellied toad with its heart shaped pupils and the green toad with its camouflage colouration that may have served as an inspiration for camouflage battle dresses. Both species depend on small bodies of water. In ideal cases, quarrying activities imitate a floodplain situation by periodically producing new aquatic habitats, which replace the old ones that were lost to succession or quarrying.

04


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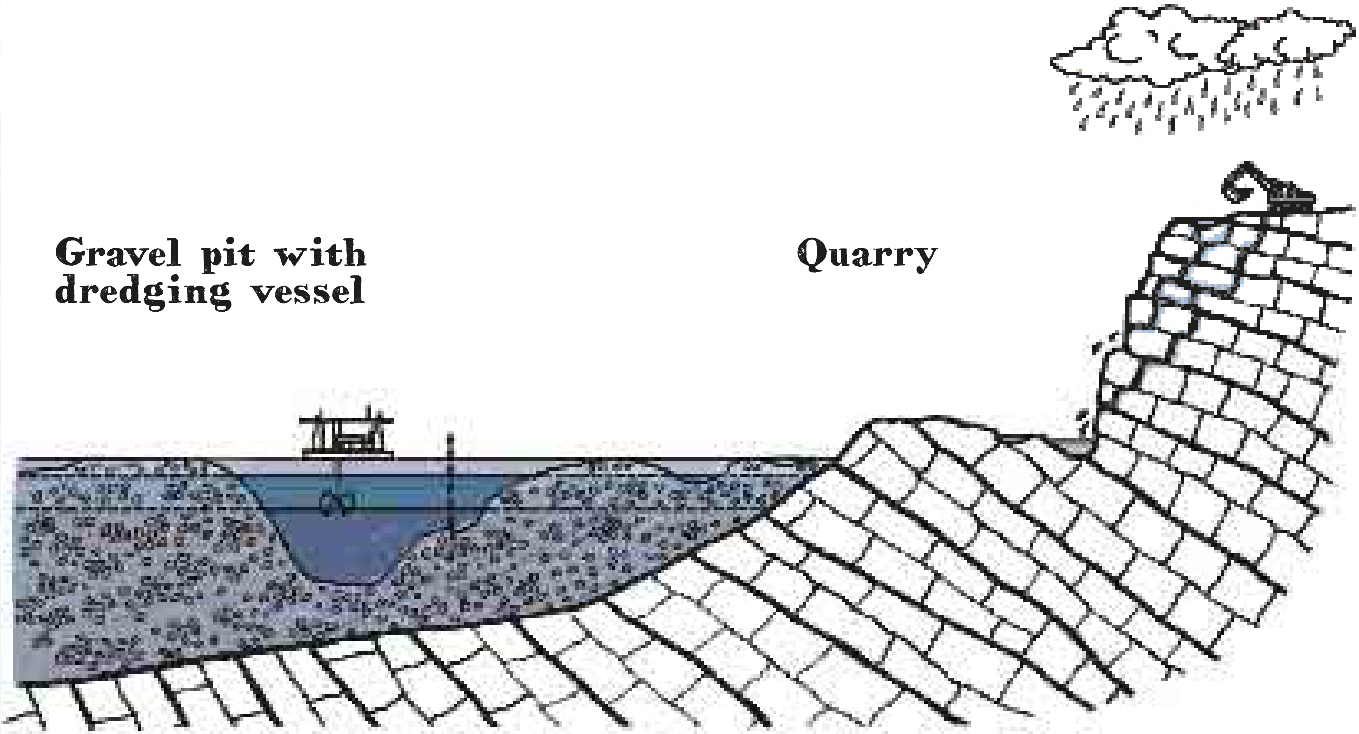
01 Breeding colonies of sand martins (*Riparia riparia*) can often be found in steep faces along the shores of gravel pit lakes.
02 The green toad with its characteristic colouration (*Bufo viridis*) is dependent on the regular new creation of small waters.

Biodiversity

The term biodiversity means global species richness. It not only refers to the total of all plant and animal species but also their genetic diversity, i.e., the variety of all genes within a given species and within all habitats and ecosystems.

02

Natura 2000 is an ecological network of protected areas in the territory of the European Union. Its purpose is the conservation of natural habitats and of wild fauna and flora of European interest. The legal framework encompasses the Habitats Directive and the Birds Directive. The former requires the establishment of Special Areas of Conservation (SACs) for habitats listed in Annex I. In Annex I are, for example, bogs, species-rich greenland or certain natural or near-natural forest types, whereas individual species are listed in Annex II. Annex IV is devoted to species in need of strict protection outside the SACs. The Birds Directive requires the establishment of Special Protection Areas (SPAs) to safeguard the habitats of migratory birds and certain particularly threatened birds.



Differences between waters in gravel pits and quarries

Gravel pit	Quarry (dry mining)
Groundwater-fed	Waters fed by rain and rock water
Changes in water level following groundwater table	Shallow waters may fall dry periodically

01 Typical wet mining scenery: dredging vessel in a gravel pit.

01

Large, permanent lakes are the most typical waters in gravel pits. In most cases, they are in contact with ground water. When gravel is quarried, the ground water gets “tapped,” and the characteristic gravel-pit lakes develop. In quarries, in contrast, the ground water usually does not become exposed (dry quarrying). Water bodies in depressions of impermeable rock are filled exclusively with spring or rain water. The differences are shown in the figure on page 44.

A sunny place

Mineral extraction sites heat up during the day and stay relatively warm at night because of their wind protected shape and the raw soils' high heat storage capacity. This makes them attractive for thermophile, often Mediterranean plants and animals. In the neighbourhood of these warm and dry sites there can be shady, north exposed steep faces or humid areas. This small-scale microclimatic variety also contributes to species richness in mineral extraction sites.

In addition, at mineral extraction sites there are often different stages of vegetation succession. They range from scarce scree vegetation over ruderal vegetation to pioneer forests that may be important land habitats of many dragonfly species.

This side-by-side occurrence of dry and moist areas covered with different types of vegetation (or almost barren) at mineral extraction sites creates a mosaic of diverse habitats.

As gravel pits concentrate along floodplains where rivers have deposited sand and gravel, they may serve as rest areas for migrating animals and favour their dispersal.

01

01 Sparse vegetation and raw soils in a wind protected, kettle-like setting – ideal conditions for many thermophile species.

02 The broad scarlet (*Crocothemis erythraea*) has been extending its range from northern Africa and southern Europe northward and has become an increasingly common sight in central Europe.

Monitoring and bioindicators

The term **monitoring** describes the continuous observation of certain plant and animal species at regular intervals. The actual state is documented and trends are determined. In this way, changes in species composition, population size, and so on, can be detected and quantified. As the life cycle of dragonflies is tightly connected to water bodies, the presence or absence of certain sensitive species can give clues about the condition of the water itself. Thus dragonflies are useful **bioindicators**.

Climate change and climatic indicators

Every creature, whether plant or animal, has certain requirements that have to be met by its biotope. Such requirements include a climatic comfort zone. As a consequence of **climate change**, associated with rising average temperatures, an increasing number of Mediterranean and thermophile species can survive and sometimes also reproduce in temperate climate zones. For dragonflies, this phenomenon of immigration is well documented. The broad scarlet (*Crocothemis erythraea*) has been expanding its range from southern Europe and northern Africa northward and has become an increasingly common sight in Central Europe. Its range expansion is still underway. It can be detected by monitoring programmes (see box p. 47) and serve as a **climatic indicator** providing evidence of global warming.

01 Sand lizards (*Lacerta agilis*) like to sit on exposed soil and sunbathe.

02 The juxtaposition of moist areas and hot and dry spots is what makes mineral extraction sites such significant animal habitats.

03 The red-winged grasshopper (*Oedipoda germanica*) is near extinction in Germany. It depends on open soils and is very susceptible to shrub encroachment.

04 Purple loosestrife (*Lythrum salicaria*) at the shallow shore of a quarry lake.

04

Succession and scrub encroachment

Succession is the sequence of different plant or animal communities naturally occurring on a site over time. The different successional stages from the species poor pioneer phase (see box) all the way to the climax successional stage fade into one another. The medium successional stages are particularly species rich, because species of early and of late sucessional stages blend into one another. Almost everywhere in Central Europe, forest is the climax successional stage. Valuable biotopes of the open landscape, such as near-natural dry grasslands that are not used or managed regularly, are always threatened by **shrub encroachment.** To permanently preserve raw soils or greenlands, shrub succession has to be removed at regular intervals or be reduced by pasturing with goats, for instance.

01 Panoramic view of a quarry – the mosaic of waters, dry areas, reeds, copses, and bare soil demonstrates how diverse mineral extraction sites can be.

Dragonflies in mineral extraction sites

Many dragonflies are threatened because their natural habitats, such as floodplains, marshes, bogs, and wet meadows were destroyed. Some of them find secondary habitats in mineral extraction sites. Each dragonfly species is adapted to and typical for a specific type of water body.

Whirring above open water...

At almost every pond and lake in gravel pits, clay pits, or quarries, the common bluet (*Enallagma cyathigerum*), the common bluetail (*Ischnura elegans*), and the azure bluet (*Coenagrion puella*) can be observed. These common damselflies often coexist with the blue and the lesser emperor (*Anax imperator* and *Anax parthenope*). Also the blue featherleg (*Platycnemis pennipes*) can be encountered at many gravel pit lakes.


01

01 Gravel pit lake with reed zone.

02 Wheel of the common bluet (*Enallagma cyathigerum*).

03 Male of the lesser emperor (*Anax parthenope*).

01 Male of the blue featherleg (*Platycnemis pennipes*).

02 A male of the azure bluet (*Coenagrion puella*).

03 Wheel of the blue emperor (*Anax imperator*).

03

01

01 Male of the blue hawker (*Aeshna cyanea*).

02 Male of the migrant hawker (*Aeshna mixta*).

03 The common darter (*Sympetrum striolatum*) with its wings in a typical position.

02

03

In the summertime, the blue hawker (*Aeshna cyanea*) can be observed at different types of water bodies. Later in the year the migrant hawker (*Aeshna mixta*) and the common darter (*Sympetrum striolatum*) may occur.

Seasoned lakes are inhabited by species whose primary habitats are natural ponds, backwaters and oxbows. Especially where there is rich aquatic vegetation, the variable bluet (*Coenagrion pulchellum*), the small redeye (*Erythromma viridulum*), or the downy emerald (*Cordulia aenea*) can be encountered.

01 Male of the variable bluet (*Coenagrion pulchellum*).

02 A water in a gravel pit lake with abundant aquatic vegetation.

03 Females of the brown hawker (*Aeshna grandis*) laying eggs at the shoreline.

04 Bladderwort (*Utricularia australis*) with its yellow flowers.


02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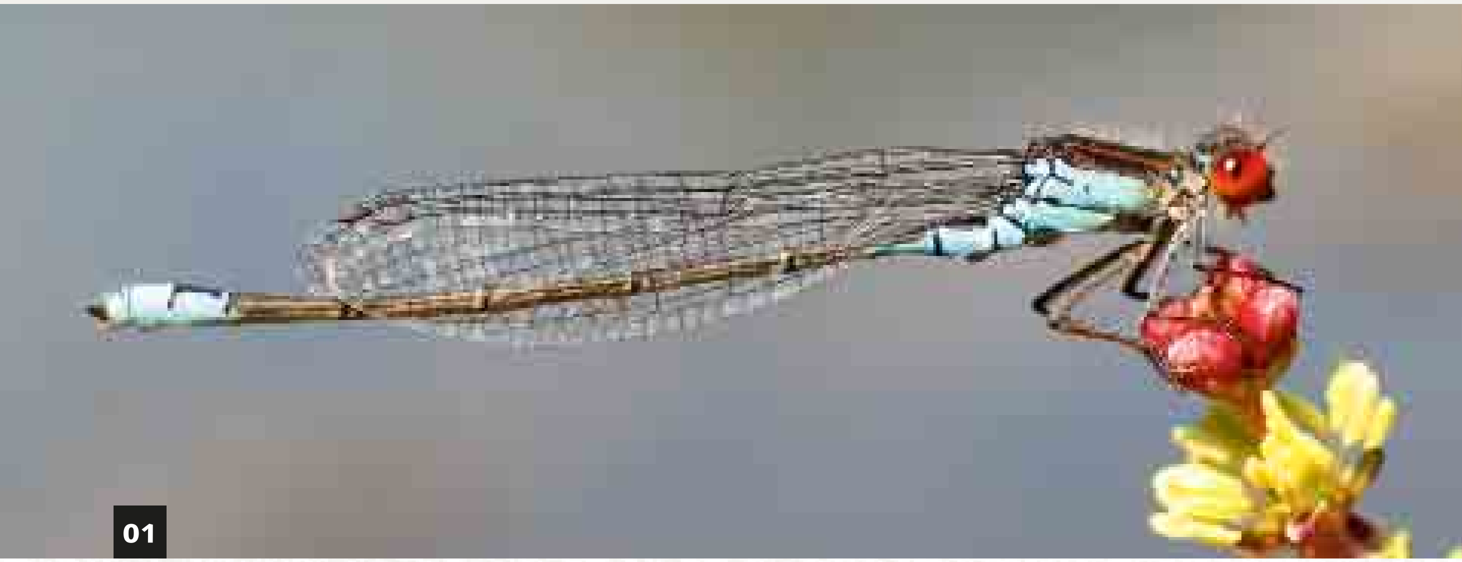


01 Male of the small redeye (*Erythromma viridulum*).

02 This scenery in a mineral extraction site resembles a natural lake waterscape.

03 A freshly emerged downy emerald (*Cordulia aenea*). In the background, the larval skin can be seen.


03

01 The four-spotted chaser (*Libellula quadrimaculata*) is unmistakable because of its wing markings.

02 A water in a gravel pit lake with abundant aquatic vegetation.

03 Male of the large red damsel (*Pyrrhosoma nymphula*).

04 Male of the green-eyed hawker (*Aeshna isoceles*).

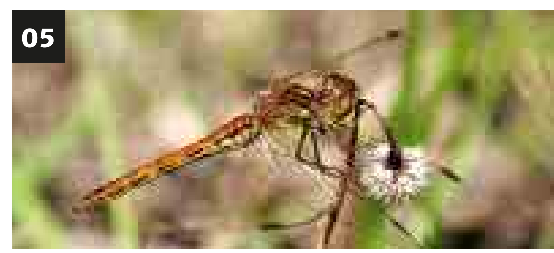
05 Female of the moustached darter (*Sympetrum vulgatum*).

06 A pond with well-developed shore vegetation.

03

Dense shore vegetation and a richly structured reed zone are preferred by the four-spotted chaser (*Libellula quadrimaculata*), the large red damsel (*Pyrrhosoma nymphula*), the green-eyed hawker (*Aeshna isoceles*), and the moustached darter (*Sympetrum vulgatum*).

04



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01 Male of the broad scarlet (*Crocothemis erythraea*).

02 Due to natural succession, the vegetationless state of new water bodies is transitory.

03 The western clubtail (*Gomphus pulchellus*).

04 Anything but bleak – a vegetationless shore of a newly created water body.

05 Male of the black-tailed skimmer (*Orthetrum cancellatum*).

04

05

The thermophile broad scarlet (*Crocothemis erythraea*) and the black-tailed skimmer (*Orthetrum cancellatum*) can be encountered chiefly at open and sunlit shores of young and sparsely vegetated gravel-pit lakes. Another typical species of this habitat is the western clubtail (*Gomphus pulchellus*).

Tarns, ponds, and water-filled wheel tracks may temporarily become dry. Such temporary waters are of great importance for dragonflies. The broad-bodied chaser (*Libellula depressa*) is a common sight, the small bluetail (*Ischnura pumilio*) something more special.

01 Temporary ponds are important dragonfly habitats.

02 A male broad-bodied chaser (*Libellula depressa*).

03 The small bluetail (*Ischnura pumilio*).

04 Freshly created shallow pond becoming dry partially or completely during the summer. In its surroundings, succession has begun.

05 In active mineral extraction sites, small temporary water bodies are created by chance.

01

The migrant spreadwing (*Lestes barbarus*) is a thermophile species that depends on sunlit shallow shore zones or small still waters with dense shore vegetation.

02

Silting and sedimentation

Aquatic habitats change over time. From the time of their creation, vegetation at the shore and in the water itself develops and spreads. Dead plant material sinks to the bottom and accumulates. The water body shrinks and becomes more and more shallow until one day it dries up. In rivers or lakes with rivers running through them, there is the additional effect of sedimentation by tiny mineral particles of silt.

01 Inundation zones, like this one with rushes and common water-plantain, are typical habitats of spreadwings.

02 In waters of advanced successional stages, the rare migrant spreadwing (*Lestes barbarus*) may occur.

03 A pair of migrant spreadwings (*Lestes barbarus*) laying eggs.

01 Small ponds and pools.

02 Male of the common spreadwing (*Lestes sponsa*).

03 Female robust spreadwing (*Lestes dryas*).

04 A wheel of small spreadwings (*Lestes virens*).

01

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For robust and small spreadwing (*Lestes dryas* and *L. virens*), inundated zones, small ponds and shallow waters are suitable habitats. All three species require sedge and rush vegetation and reproduce mostly at temporary waters.

01

01 Willows at the shore of a gravel pit lake.

02 Western willow spreadwing (*Lestes viridis*).

03 Willow spreadwings (*Lestes viridis*) laying eggs.

02

03

The western willow spreadwing (*Lestes viridis*) lays its eggs into the soft tissue of young twigs of trees and shrubs. The females tuck their eggs beneath the bark using their ovipositor. There, the willow spreadwings hibernate in the egg stage. The following spring, they hatch into tiny prolarvae which plunge into the water. Therefore, willow spreadwings can only be found in aquatic habitats where branches of trees or shrubs spread out over the water.

01 Shallow puddles are created more or less accidentally during exploitation and provide valuable biotopes. In the foreground, swarms of tadpoles can be seen.

02 Blue-eyed hawker (*Aeshna affinis*).

03 Male of the southern skimmer (*Orthetrum brunneum*).

04 Wheel of the keeled skimmer (*Orthetrum coerulescens*).

05 The red-veined darter (*Sympetrum fonscolombii*).

06 Rivulet in a gravel pit.

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The keeled skimmer (*Orthetrum coerulescens*) can sometimes be found in rivulets and ponds fed by spring water.

The red-veined darter (*Sympetrum fonscolombii*) and the southern skimmer (*Orthetrum brunneum*) prefer pools with shallow shores that are surrounded by open plains of loam or gravel. The blue-eyed hawker (*Aeshna affinis*) is specialised in temporary waters. Its females deposit their eggs on dried up beds of temporary waters. These three species occur more or less frequently in mineral extraction sites.

01

Protection of dragonflies

Many dragonfly species are threatened. Therefore, in Germany for instance, all species are protected by law and must not be caught or collected.

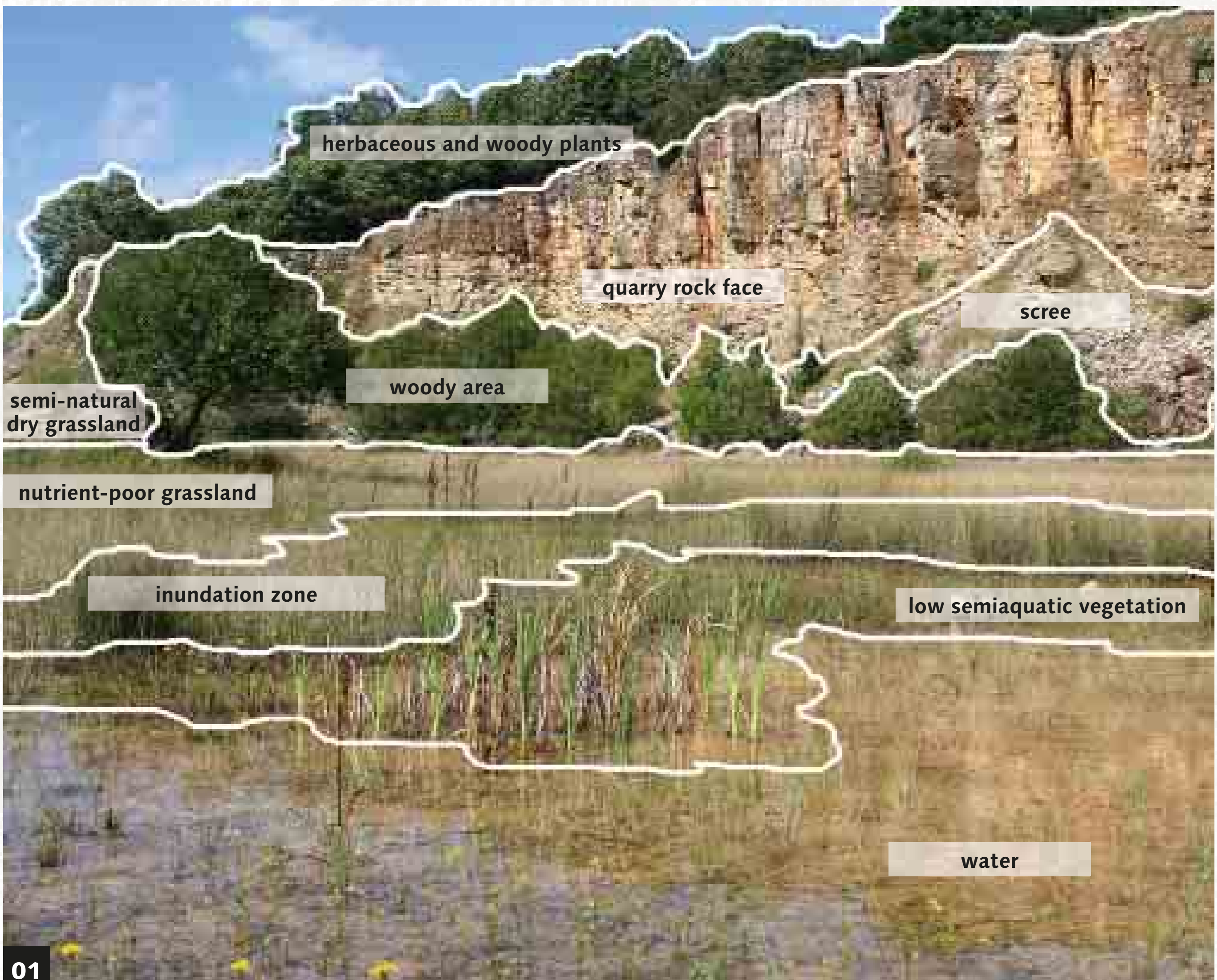
Above all, the loss of natural habitats due to building activities and intensive farming has led to the decrease of many dragonflies in the past decades.

The conservation of existing or creation of new near-natural waters and their surroundings plays an important role in the protection of dragonflies. Well-structured cultural landscapes and ecologically sustainable farming without excessive use of pesticides are important for dragonflies.

They also profit from the creation of new near-natural ponds or from renaturation of flowing waters. Habitat management on a regular basis can be pivotal for survival of a species at a certain place. For example, the mercury bluet (*Coenagrion mercuriale*) is a species of the Habitats Directive (see box Natura 2000 p. 43) and depends on regular but careful mowing of the sides of meadow brooks and ditches.

01 Shallow waters at an early successional stage are important habitats for numerous dragonfly species.

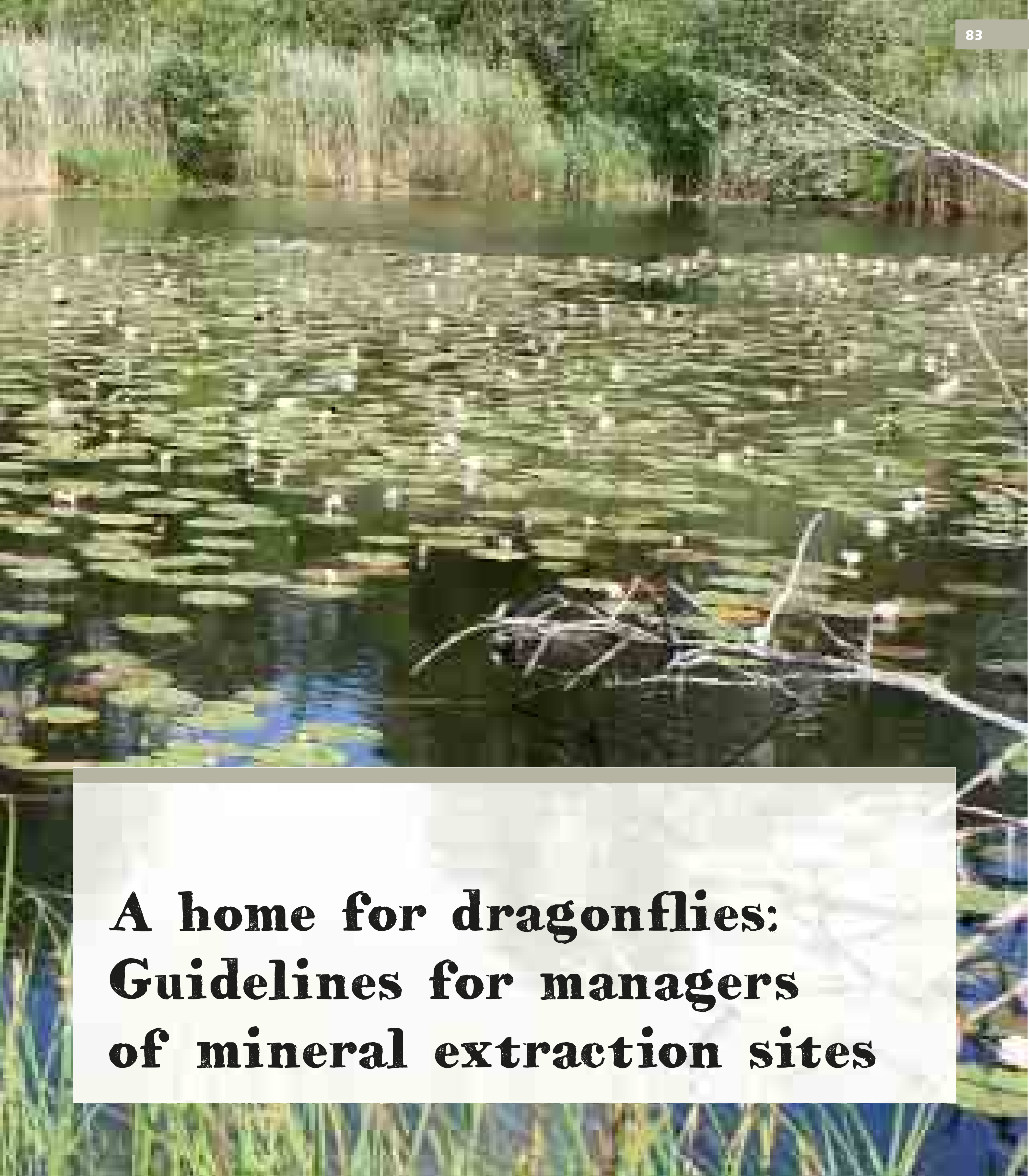
Diversity of habitats



01 Biotope compartments in a quarry. The juxtaposition of wet and dry, vegetated and exposed soils creates many transition zones, which are of extra high value for plants and animals.

02 In spite of ongoing mineral extraction, this quarry displays an impressive diversity and offers habitats for many rare plants and animals.

02



A home for dragonflies: Guidelines for managers of mineral extraction sites

For many dragonflies, the existence of shallow shores with reed zones und aquatic vegetation is of special importance. Some species primarily colonise large gravel-pit lakes with open water; others prefer small aquatic habitats that lack vegetation. Some occur at small, silt-filled aquatic habitats with dense shore vegetation and others at virgin clay pools.

How to do it...

The shore zones of all aquatic habitats ought to be ample and shallow. Large mineral extraction sites that have a combination of fluctuating water levels and zones of aquatic, reed, and sedge vegetation provide a multitude of habitats; they should receive a very high priority.

A varied shore morphology with bays and headlands prolongs the shoreline with its important habitats and also creates areas that are sheltered from the wind.

01

02

01 Reed zone (*Phragmites australis*) and yellow pond-lily (*Nuphar lutea*).

02 Shores of ponds and lakes in mineral extraction sites ought to be formed as diverse as possible.

The less the better!

Planting trees and shrubs along shorelines doesn't make sense. They only lead to undesirable shading and suppression of pioneer vegetation and the reed zone. As a matter of principle, the nutrient-poor skeletal soils must not be covered with topsoil or planted with trees and shrubs.

Shoal inundation zones with ephemeral and persistent small pools and micro-aquatic habitats are of much higher importance for rare and endangered dragonfly species than large gravel-pit lakes.

It is important to create and maintain a mosaic of different stages of natural plant succession. Management should aim at creating habitats for species of both early and late successional stages. Therefore, each time only part of the water bodies of a mineral extraction site should be managed by cutting of woody plants or dredging. Ideally, additional small water bodies are created in the course of management.

As noted above, shallow shorelines are important. Fish must not be introduced in any water body because they feed on dragonfly larvae and are harmful for larvae of many rare amphibian species as well. Recreational use should be banned or be restricted to special areas.

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01 Artificially created pond – the cutting of woody plants at regular intervals is mandatory in order to keep the water from becoming more and more overgrown and shady.

02 Temporary waters in a quarry.

03 Inundated zones with reed succession.

04 European white water-lilies (*Nymphaea alba*).

01 Mineral extraction sites may host valuable wetlands.

02 Exposed soil in a quarry.

03 Four-legged helpers: Exmoor ponies as landscape workers in a gravel pit.

04 In mineral extraction sites, some areas should always be kept free of woody plants in order to preserve sunny pioneer sites.


03


04

Open gravel plains should be preserved permanently following exploitation. To achieve this, shrub encroachment must be reversed by removing woody plants at about two-year intervals. Open pioneer zones can be recreated periodically using bulldozers or other machinery as it is done in active mineral extraction sites when preparing new mineral extraction sites. Open areas serve as land habitats and hunting grounds for many dragonfly species.

As a basic principle, compensatory habitats should be created in adjacent post-use areas before new mineral extraction sites are developed. This practice ensures that plants and animals that would otherwise become "homeless" have a chance to move into these new habitats.

All management operations that involve pruning and wood cutting should be carried out between October and the end of February so no nesting birds are harmed. The time between the end of September and the end of October is best for management operations at existing aquatic habitats so that hibernating amphibians are impacted as little as possible.

01 Wet area in a quarry.

02 Uprooting of woody plants in a gravel pit.

03 Shallow water with cattails.

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Scientific species name	English species name	Red List category Europe	Habitat directive	Gravel pits				
				KG Hardtwald	Forchheim	Neukloster	Langhagen	Hannover Nord
Calopteryx splendens	Banded Demoiselle	·	·	X	·	O	O	·
Lestes barbarus	Migrant Spreadwing	·	·	X	·	·	·	·
Lestes dryas	Robust Spreadwing	·	·	·	·	·	·	·
Lestes sponsa	Common Spreadwing	·	·	O	O	X	X	X
Lestes virens	Small Spreadwing	·	·	X	X	·	·	·
Lestes viridis	Western Willow Spreadwing	·	·	X	X	X	X	X
Sympecma fusca	Common Winter Damsel	·	·	X	X	·	X	X
Platycnemis pennipes	Blue Featherleg	·	·	X	O	X	X	X
Coenagrion hastulatum	Spearhead Bluet	·	·	·	·	·	·	·
Coenagrion puella	Azure Bluet	·	·	X	X	X	X	X
Coenagrion pulchellum	Variable Bluet	·	·	·	·	·	X	·
Enallagma cyathigerum	Common Bluet	·	·	X	X	X	X	X
Erythromma lindenii	Blue-eye	·	·	X	X	·	·	·
Erythromma najas	Large Redeye	·	·	·	O	·	X	·
Erythromma viridulum	Small Redeye	·	·	X	X	·	O	X
Ischnura elegans	Common Bluetail	·	·	X	X	X	X	X
Ischnura pumilio	Small Bluetail	·	·	X	O	·	·	X
Pyrrhosoma nymphula	Large Red Damsel	·	·	·	O	·	O	·
Aeshna affinis	Blue-eyed Hawker	·	·	X	·	·	·	O
Aeshna cyanea	Blue Hawker	·	·	·	O	·	O	·
Aeshna grandis	Brown Hawker	·	·	X	O	·	X	·
Aeshna isoceles	Green-eyed Hawker	·	·	X	·	·	X	·
Aeshna juncea	Moorland Hawker	·	·	·	·	·	·	·
Aeshna mixta	Migrant Hawker	·	·	X	X	X	X	X
Anax imperator	Blue Emperor	·	·	X	X	O	X	X
Anax parthenope	Lesser Emperor	·	·	X	O	·	X	·
Brachytron pratense	Hairy Hawker	·	·	·	·	·	X	·
Gomphus pulchellus	Western Clubtail	·	·	X	·	·	·	·
Gomphus vulgatissimus	Common Clubtail	·	·	X	·	O	X	·
Onychogomphus forcipatus	Large Pincertail	·	·	X	O	·	·	·
Ophiogomphus cecilia	Green Snaketail	·	II, IV	X	·	·	·	·
Cordulia aenea	Downy Emerald	·	·	X	X	·	X	·
Somatochlora flavomaculata	Yellow-spotted Emerald	·	·	X		·	·	·
Somatochlora metallica	Brilliant Emerald	·	·	X	O	O	X	·
Crocothemis erythraea	Broad Scarlet	·	·	X	X	·	·	O
Leucorrhinia caudalis	Lilypad Whiteface	NT	IV	·	·	·	X	·
Leucorrhinia dubia	Small Whiteface	·	·	·	·	·	·	·
Libellula depressa	Broad-bodied Chaser	·	·	X	·	X	X	O
Libellula fulva	Blue Chaser	·	·	·	·	·	X	·
Libellula quadrimaculata	Four-spotted Chaser	·	·	X	X	·	X	X
Orthetrum brunneum	Southern Skimmer	·	·	X	·	O	·	X
Orthetrum cancellatum	Black-tailed Skimmer	·	·	X	X	X	X	X
Orthetrum coerulescens	Keeled Skimmer	·	·	X	·	·	·	X
Sympetrum danae	Black Darter	·	·	X	·	X	X	·
Sympetrum fonscolombii	Red-veined Darter	·	·	X	O	·	·	X
Sympetrum sanguineum	Ruddy Darter	·	·	X	X	·	X	X
Sympetrum striolatum	Common Darter	·	·	X	X	·	X	X
Sympetrum vulgatum	Moustached Darter	·	·	X	O	X	X	X
Number of species				**37**	**28**	**16**	**31**	**22**

Meaning of European Red List category NT: near threatened

	Gravel pits		Quarries									Steadiness
	Hannover Süd	Stolzenau	Nussloch	Burg-lengenfeld	Sengenthal	Lengfurt	Ennigerloh	Geseke	Schelklingen			
									Vohen-bronnen	Gerhausen	Sotzen-hausen	
	·	O	·	O	·	·	O	·	·	·	·	6
	·	·	·	X	X	X	·	·	·	·	·	4
	·	·	·	X	X	O	·	·	·	·	·	3
	·	·	·	X	X	·	·	X	X	X	X	11
	·	·	·	X	X	·	·	·	·	·	·	4
	·	·	X	X	·	X	·	·	X	·	·	9
	X	·	·	X	·	·	·	·	·	X	X	8
	·	·	·	X	·	O	X	X	·	·	·	9
	·	·	·	·	O	·	·	·	·	·	·	1
	O	X	·	X	X	·	X	X	·	·	·	11
	·	·	·	·	·	·	·	·	·	·	·	1
	X	X	·	X	X	O	X	·	O	X	X	14
	·	·	·	·	·	·	·	·	·	·	·	2
	·	·	·	O	·	·	·	·	·	·	·	3
	X	·	·	·	·	·	·	·	·	·	·	5
	X	X	X	X	X	X	X	X	O	O	·	15
	O	·	·	X	O	X	X	X	·	O	·	10
	·	·	·	X	X	·	·	·	·	·	·	4
	O	·	O	·	·	·	·	·	·	·	·	4
	X	·	O	X	X	O	·	X	X	O	O	11
	·	·	·	O		·	·	·	·	·	O	5
	O	·	·	·	·	·	·	·	·	·	·	3
	·	·	·	·	·	·	·	·	·	O	O	2
	·	X	·	X	O	O	·	·	·	·	O	10
	X	O	X	X	X	O	X	O	·	O	·	14
	O	·	·	O	·	·	·	·	·	O	·	6
	·	·	·	·	·	·	·	·	·	·	·	1
	·	·	·	X	·	·	O	·	·	·	·	3
	·	·	·	·	·	·	·	·	·	·	·	3
	·	·	·	X	·	·	·	·	·	·	·	3
	·	·	·	·	·	·	·	·	·	·	·	1
	·	·	·	O	·	·	·	·	·	·	·	4
	·	·	·	·	·	·	·	·	·	·	·	1
	·	·	·	·	·	O	·	·	·	·	·	5
	O	O	·	·	·	·	X	·	·	O	·	7
	·	·	·	·	·	·	·	·	·	·	·	1
	·	·	·	·	O	·	·	·	·	·	·	1
	O	X	·	X	X	·	X	X	·	·	·	10
	·	·	·	·	·	·	·	·	·	·	·	1
	X	X	·	O	X	·	X	X	·	·	·	10
	X	·	·	·	O	O	X	X	·	O	·	9
	X	X	X	X	O	X	X	O	·	O	·	14
	X	·	·	·	·	·	X	O	·	·	·	5
	·	·	·	O	X	·	·	·	·	O	·	6
	·	·	·	X	·	·	·	·	·	·	·	4
	X	·	X	X	X	X	X	·	X	X	X	13
	X	X	X	X	·	X	X	X	X	X	X	14
	X	X	·	X	X	·	X	X	X	O	·	13
	20	**12**	**8**	**30**	**21**	**15**	**17**	**14**	**8**	**16**	**9**	**48**

X: species reproducing at the site; O: reproduction not proven

Kalkman et al. (2010): European Red List of Dragonflies. Luxembourg: Publications Office of the European Union.
Many of the species in this compilation are found in the national Red Lists.

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Cover picture: young male of the common bluet (*Enallagma cyathigerum*). Photo by David Veer.

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