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HEIDELBERGCEMENT

Butterflies and other insects in quarries and gravel pits

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in mineral extraction sites

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Preface

Walking through a mineral extraction site on a warm sunny day, the ground comes alive with six-legged creatures of all different shapes and sizes thriving within the unique habitats associated with our industry. These, of course are insects – probably the most forgotten and unappreciated group of animals, and yet the most diverse and fascinating when you get down on your hands and knees and enter into their mysterious miniature world.

There are about 1.100.000 different species of insect in the world, with new species still being discovered all the time. They can fly, crawl, jump, swim – some even walk on water! Insects play a crucial role in a healthy environment, helping to break down and dispose of waste, providing a food source for many other animals and acting as pollinators, for which we rely on heavily for our own food production.

So what makes quarries and gravel pits in such a rich playground for this diverse group? Quarries – both active and rehabilitated – offer a large variety of different habitats, topographical features and microclimates to suit all the requirements of this wide-ranging group of animals. Many rare species of insects are dependent on the nectar or plant material of very specific plant species that are often associated with early pioneer stages of vegetation growth – a habitat type often in abundance within our quarry sites. The vast areas of bare ground and vertical walls provide ideal conditions for burrowing insects. Low nutrient levels encourage species-rich grasslands which generate ample nectar during spring and summer, fuelling the critters who flourish there. Both small temporary waterbodies and more permanent ponds provide aquatic insects with rich breeding grounds, as already described within our first book that focussed on dragonflies.

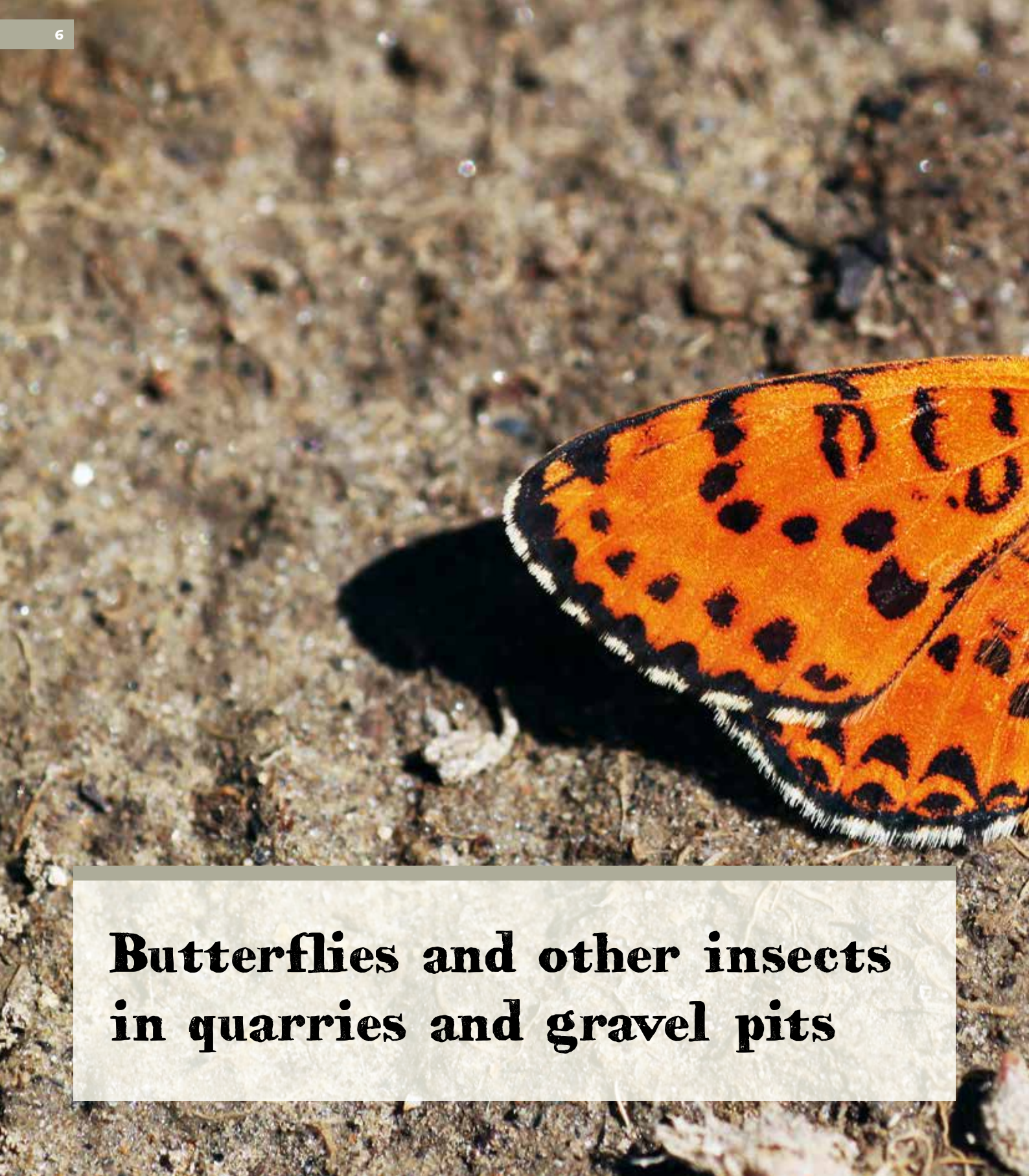
Insects are very sensitive to environmental change and are important indicators of habitat quality. The vast array of species observed within our quarries is a testament to the high quality of the habitats that can be found at our sites, providing important opportunities for not only this group, but for wildlife in general.

This book is the sixth in our biodiversity book series and examines this intriguing animal group. You will find that the book has a strong focus on the most popular insect group: butterflies. Found across the world in a myriad of colours and patterns, this fluttering creature is quick to grab people's attention and emotion. However, the huge variety of other insect species that also find refuge within our quarries deserve equal attention, I hope that you find them as fascinating and beautiful as I do.

Please enjoy your literary journey into the world of insects.

Dr Carolyn Jewell

Biodiversity and Natural Resources Manager
Global Environmental Sustainability
HeidelbergCement



Butterflies and other insects in quarries and gravel pits

A giant motley crew of tiny critters – the realm of the insects

Insects are the largest group within the whole animal kingdom. This refers to both number of species and number of individuals. Almost one million insect species are known so far. Scientists estimate that three to five million additional species have not yet been discovered. Insects occur in all terrestrial habitats, with their abundance being highest in the tropics, but they are also widespread in temperate zones. Apart from terrestrial habitats they also colonise aquatic habitats – either exclusively in their larval stages or during their complete life cycle.


01

Sizes range from tiny dwarf wasps measuring only 0.13 millimeters to the 17 centimeters gigantic Hercules beetle. The variety of shapes is immense as well.

01 Enchanting: The false heath fritillary (*Melitaea diamina*).

02 This froghopper species (*Ceropis vulnerata*) lives in humid grasslands where it sucks sap from plants.

03 The musk beetle (*Aromia moschata*) is part of the longhorn beetle family; its iridescent body shines in all the colours of the rainbow.

04 Three chalkhill blues (*Lysandra coridon*) have gathered on a grass spike where they will spend the night.

01

When looking at them closely, insects are fascinating and often very beautiful. Graceful butterflies and lightning-fast dragonflies are popular representatives. But grasshoppers, beetles, true bugs, bees, and even flies deserve attention. Many insect species are colourful and conspicuous, others, in contrast, are well-camouflaged and almost invisible in their habitats.

01 Robberflies such as *Machimus rusticus* are skilful predators that feed on other insects.

02 The lesser purple emperor (*Apatura ilia*) lives at forest edges and in clearings.

03 The colour of the green hairstreak (*Callophrys rubi*) makes for an excellent camouflage in bushes where predators such as birds can hardly spot this delicate butterfly.

01 Here's looking at you! Frontal view of a blue.

02 En garde! Two heath bee flies (*Bombylius minor*) take a rest on a rush flower. These fluffy nectar feeders with their characteristic long suckers belong to the fly family. Their larvae live as parasites in the nests of bees and other insects.

03 Every child knows and worships the beneficial ladybird (*Cocinella septempunctata*) as a lucky charm.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Of lice and men

Insects! Not only do we have the image of crop pests and obnoxious "bugs", but some insects' bites and stings can also be uncomfortable or even dangerous to humans. Lice, fleas, and mosquitoes are notorious.

Most insects, however, are completely harmless to people and many are extraordinarily helpful. Here are some examples:

Some insect species feed on other insects. These "beneficial insects", such as the larvae of ladybirds (*Cocinella septempunctata*), common green lacewings (*Chrysoperla carnea*), and ichneumon wasps can control populations of aphids or plant lice without a single drop of poison – they are the gardener's friends. Some species are available commercially as a type of "biological control".

Honey bees (*Apis mellifera*) were domesticated a long, long time ago by the old Egyptians. This species is not only important as a honey producer; more importantly, it plays a key role in pollinating our fruit plants.

The caterpillar of the domesticated silk moth – the silkworm – produces the raw material for one of the most valuable fabrics: silk! This exceptional moth species has been bred in Asia for centuries.

Predominantly in Asia and Africa, fried, deep-fried, or even prepared with honey, insects are an important part of the local people's diet. Large grasshoppers, caterpillars, and true bugs are important protein sources, and in many Asian countries, insects are specifically reared for this purpose.

03

01 The predatory snake fly (*Raphidoptera*) feeds on other insects' eggs and larvae.

02 The peacock butterfly (*Inachis io*) is a common butterfly. Its caterpillars feed on stinging nettles.

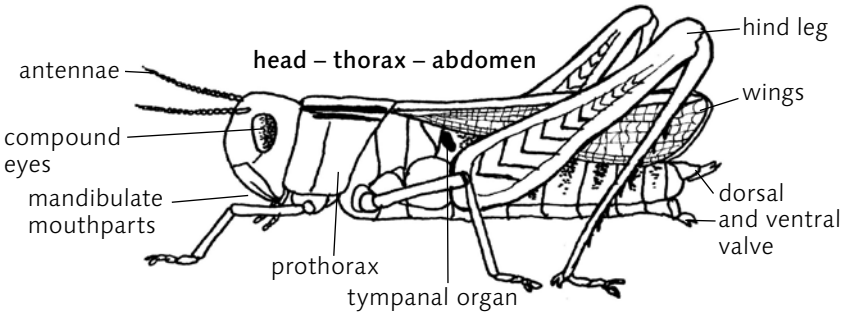
02

Hoppers and gliders – the many designs of insects

In spite of their great variety in shapes and colors all insects are characterised by the following common traits: They have no bones but an exoskeleton made of chitin. Their body consists of three parts: head, thorax, and abdomen. All have three pairs of legs which come in many different shapes dependent on species.

The anatomy of a grasshopper

(after Bellmann 1993)



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01 The forewings of beetles are thickened and hardened into shell-like structures called elytra. They protect the transparent pair of hindwings which are only released from the protection of the elytra when needed for flying. This picture shows a longhorn beetle (*Dorcadion fuliginator*).

02 All wings: butterflies are characterised by their large fore and hind wings. This photo shows a ringlet (*Aphantopus hyperantus*).

03 The front legs of the European mole cricket (*Gryllotalpa gryllotalpa*) are shaped like shovels, allowing the animal to dig its burrows.

01 The front legs of the praying mantis (*Mantis religiosa*) are optimised in order to rapidly seize its prey.

02 Dragonflies, in this case a female banded demoiselle (*Calopteryx splendens*) damselfly, have powerful flight muscles and are excellent fliers. Their legs bear long bristles. Together they form a net used to seize their prey in flight.

03 The hind legs of grasshoppers have developed into mighty jumping legs. This is a water-meadow grasshopper (*Chorthippus montanus*).

Every insect species has its own habitat demands. Of course there are some generalist species which occur in urban areas too. However, most insects have very specific requirements, as many species need certain plants as food for either the adult insect or the larva. The availability of specific structures and microclimatic conditions are often mandatory for successful reproduction and long-term survival. The more variable and richer the structures present in a landscape, the more species find suitable niches in which to survive. Insects are important indicators of the ecological state of landscapes being very sensitive to environmental change.


01


02

01 The Queen of Spain fritillary (*Issoria lathonia*) lives in calcareous heathlands and dry mineral extraction sites. The caterpillars feed exclusively on field pansies.

02 Field pansy (*Viola arvensis*).

03 The larvae of this wasp-like nomad bee species (*Nomada fucata*) live as parasites in the nests of other bee species and thus depend directly on them.

04 Berger's clouded yellow (*Colias alfacariensis*) depends on horseshoe vetch (*Hippocrepis comosa*) as food for its caterpillar. This picture shows a female laying eggs.

05 This ground beetle species (*Broscus cephalotes*) prefers sandy soil.

03

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Butterflies are certainly the most beloved and popular insects. They are the embodiment of gracefulness and beauty, featuring often in poetry and visual arts. Their fluttering radiates happiness and joie de vivre – a reason why butterflies appear in many children's songs and poems. The metamorphosis of a caterpillar via the pupa to a butterfly is one of the most impressive natural wonders. In ancient Greece, butterflies were symbols of rebirth and immortality. With 106,000 species known so far globally, lepidopterans are the second largest insect group.

01, 02 The small blue (*Cupido minimus*) is the smallest central European butterfly. Its caterpillars feed exclusively on kidneyvetch. The eggs are laid into the flowers.

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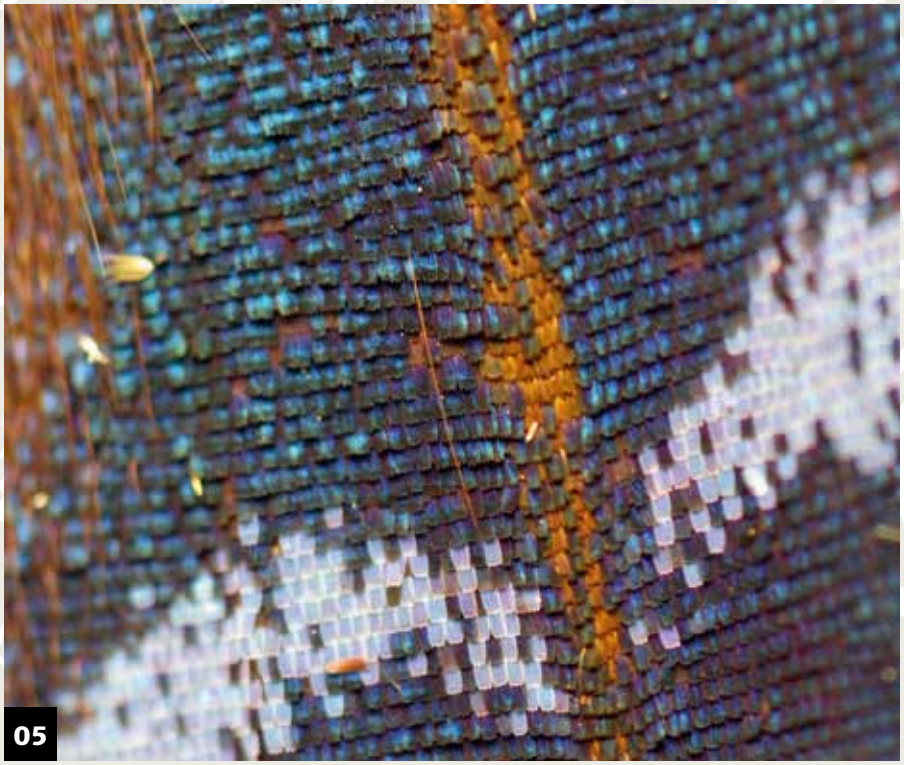

05

03 The small heath (*Coenonympha pamphilus*) is a common butterfly. Its caterpillars are generalists and feed on a diverse range of grass species.

04 The common blue (*Polyommatus icarus*).

05 A butterfly's wing is covered with colourful scales that resemble tiny roof tiles. The scales are derived from hairs.

01 The light from above shows the leaf-like veins of the common brimstone (*Gonepteryx rhamni*). It is one of the few butterfly species that hibernates as an adult and not in the pupal stage. An antifreeze liquid in its body enables it to survive harsh winter temperatures.

02 The mother of pearl moth (*Pleuroptya ruralis*) is a representative of the moth group.

03 The mallow skipper (*Carcharodus alceae*) strikes this special pose so the sun can warm it up more quickly in the early morning hours.

Lepidopterans – sun worshippers and night owls

Lepidopterans (butterflies and moths) have a very typical appearance. The head bears long antennae, large compound eyes, and a long proboscis that can be coiled when not in use. Both sides of the two wing pairs are covered with fine, coloured scales that are derived from flattened hairs. Colours and patterns vary according to species. Moths are more compactly built and they usually fold their wings like a roof over their abdomen when at rest. Butterflies, in contrast, fold up their wings vertically so that the lower wing sides are visible. Butterflies need to be warmed up by the sun in order to become ready for take-off, while moths warm up their flight muscles by actively contracting their flight muscles.

Most moths are nocturnal and have dull colours and brownish or grey patterns in order to stay well hidden while resting during the day on tree bark or dry leaves. Diurnal moth species, in contrast, often display vivid, contrasting warning patterns to show predators that they taste bad or are even poisonous. It is called mimicry when they just imitate poisonous species but are in fact tasty.

Butterflies are active during the day. The upper sides of their wings are usually brightly coloured and therefore conspicuous, while the lower sides bear camouflage patterns.

Moths have threadlike antennae, while butterflies have clubbed antennae. Male moths often have feathery antennae – this is a method to enlargen the surface area of their antennae in order to better detect female pheromones (see side bar p. 41).


02


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Flower-children and pollen thieves – insect appetites

The diet and feeding behaviour of insects is just as diverse as their body shapes and habitat requirements. This is reflected in the wide variety of mouth-part structures found within the group.

01

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01 The proboscis of butterflies is coiled up when not needed as can be seen in this orange tip (*Anthocharis cardamines*).

02 Lepidopterans have a long straw-like appendage called a proboscis which is unique to the insect kingdom. It allows them to suck nectar from flowers, as can be seen in this lesser marbled fritillary (*Brenthis ino*).

03 Some Flies (Diptera) like the one in this picture have a sponge-like mouth with which they can take up liquids. The mouthparts of the closely related mosquitoes have developed into a stinging apparatus used to penetrate the skin and suck blood from mammals or birds.

04 The nut weevil (*Ciurculio nucum*) belongs to the family of true weevils or "snout beetles". Its mouthparts are situated at the tip of its long snout.

03

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True bugs and plant lice have a piercing proboscis with which they suck plant liquid from stalks or leaves. Other true bugs are predatory and feed on other insects.

01 This shield bug species (*Graphosoma lineatum*) prefers sucking sap from ripening seeds of umbellifer plants.

02 The wart-biter's (*Decticus verrucivorus*) name refers to its mighty mandibles. He eats plants but other insects as well.

03 Beetles such as this blue ground beetle (*Carabus intricatus*) have strong mandibles.

Grasshoppers, dragonflies, wasps, and many beetles have chewing-type mouthparts. Some species feed only on plants, others on animals, and some eat both.

All bees – a large insect group with, for instance, 1,965 known European species – visit flowers and play a crucial role as pollinators of crop plants. Many of them are highly specialised with regard to both their food plants and their nesting requirements.

01 A Fabricius nomad bee (*Nomada fabriciana*) visits a flower.

02 The males of this longhorn bee (*Eucera nigrescens*) have unusually long antennae. They mostly collect pollen at bush vetch flowers (*Vicia sepium*).

03 The caterpillars of many butterfly species are strongly dependent on single food plants; these may vary regionally. In southwestern Germany, the caterpillars of this northern blue (*Lycaeides idas*) feed exclusively on common broom (*Cytisus scoparius*).

Food specialists

Animals that feed on one specific food source are called **monophagous**. This extreme adaption is mostly found in the tropics where exuberant species richness has favoured such close ties between one animal and one specific plant.

In Europe, many butterflies and bees are **oligophagous**, i.e. their diet is limited to a small number of species, usually from one taxonomic family. One example is the group of 'blue' butterflies that is restricted to nectar from plants in the legume family. The caterpillars of many butterfly species feed on specific food plants; so that their offspring can eat right after hatching, the females lay their eggs on just the right plants.

Animals that eat plants exclusively are called **herbivorous**. In this sense, cows are the same as grasshoppers. Some insects are predators and feed on larvae and adults of other insects. This feeding behaviour is called **carnivorous**. Dragonflies are a good example. Many insect species are **omnivorous** – just like most humans. This means that their diet consists of both plants and animals.

01

01 A female of the European oil beetle (*Meloe proscarabaeus*) is eating.

02 This grey-backed mining-bee (*Andrena vaga*) constructs its nests in the soil and is the host of the larvae of European oil beetles.

03 The mining-bee crawls into its nesting burrow.

Oil beetles of the genus *Meloe* are feeding specialists. The beetles themselves eat all kinds of herbs. The very fertile female beetles lay up to 40,000 eggs. The tiny larvae that hatch from the eggs sit on flowers and attach themselves to visiting insects. The larvae can only develop, however, when they manage to attach to this specific host bee species.The host mining-bee then inadvertently carries them back to the nest where the beetle larvae feast on the host species' larvae.

01

Lepidopterans just love flowers. Almost all butterflies, and many moth species, suck nectar from a wide variety of flowers. Therefore, lepidopterans need abundant flowering plants in order to fill their bellies. The more diversely structured a landscape – with meadows, slopes, and copses – the more nectar sources are available, providing better conditions for lepidopterans.

02

Many species take up liquids from moist soil. Butterflies also concentrate on where tree sap exudes and on fruits, faeces, or carrion. Here, they satisfy their nutrient salt needs.

With few exceptions, central European butterflies feed on a wide array of plant flowers. The caterpillars, however, are often dependent on one specific plant or a small selection.

01 A grizzled skipper (*Pyrgus malvae*) on a lesser knapweed (*Centaurea nigra*).

02 A special guest at the breakfast table: the two-tailed pasha (*Charaxes jasius*) lives in the Mediterranean and is Europe's largest butterfly. It likes to suck at overripe fruit.

03 Tropical butterflies are taking up water from moist soil.

The string section

Male birds sing their songs to attract females and stake their claim. Quite a few male insects – notably grasshoppers, crickets, and cicadas – bewitch their females in the same manner.

Almost all grasshoppers and crickets produce sounds. Most people are familiar with the chirping concerts of field crickets that make a walk through the fields on a warm summer evening just perfect. In the Mediterranean, as well as in many tropical regions, the incredibly loud rattling sound of tree cicadas is the soundtrack of summer.

01 A common field grasshopper (*Chorthippus brunneus*) moves its hind legs rapidly up and down against its wings to produce a whirring sound.

02 Cicada (*Cicada orni*) from southern France.

Stridulation – nature's string symphony

Most insects produce sounds by rubbing body parts against each other.

Typically, a structure with a toothed ridge on the wing edges or legs ("plectrum") is being moved across a finely-ridged surface ("washboard") on wings or lateral body parts. This results in a chirping or fiddling noise. This way of producing sounds is called **stridulation**.

Other insects, including some beetles and grasshoppers, produce sounds by moving their mandibles against each other – a more musical teeth grinding.

02

Ear here?!

The hearing organ in some insects, the so-called **tympanal organ**, can be situated in just about any part of the insect. It is a membrane stretched across an air sac that has sensory receptor cells sitting on a thin part of the cuticula. It works like an eardrum, or tympanum. In crickets and some grasshoppers the tympanal organ is located in the front leg. In other grasshoppers, as well as in cicadas and butterflies, it sits in the thorax or abdomen.

The sense of hearing plays in important role for many grasshopper and cicada species. By arranging their "listening legs", crickets can locate stridulating rivals and use this spatial information to defend their own territory.

Gettin' bzzzy – reproductive behaviour in insects

How do male and female flying insects find each other during the mating season? Many of them are very mobile and on the wing all day, so they often meet more or less accidentally within their habitats. Due to the close ties most species have to specific habitats, the likelihood of such encounters is augmented. Certain landscape structures can be important as rendez-vous sites for some butterflies (see side bar p. 39).

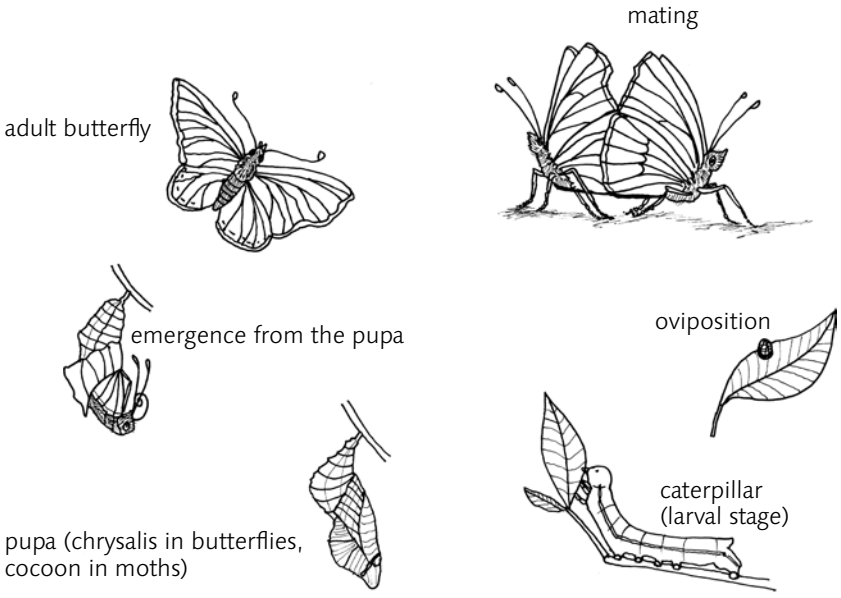
In some insect species, the males fly around all day in search for females, whereas in others the males wait leisurely for a female to pass by. In many moths, specific scents – pheromones – play a key role in finding a partner (see side bar p. 41).

When it comes to romance, the male grasshopper goes all out with courtship songs to seduce the females. Scientists hypothesise that the females can judge the fitness of a male by evaluating the quality of its songs. A sophisticated and enduring stridulation performance can only be delivered by a healthy, strong male with good genes.

01

Example for holometabolism

complete metamorphosis: life cycle of a butterfly



Hilltopping

In order to find a partner, both sexes of some butterfly species move to exposed hilltops with favourable updrafts. The males appear first and defend as much space of the hill against competitors as they can. Then the females appear and pick a partner.

This behaviour is called **hilltopping**, and is mostly exhibited in dispersed and rarer butterflies such as common yellow swallowtails and scarce swallowtails respectively.

01 This male large copper (*Lycaena dispar*) on the right is courting a female.

02 Mating black-veined whites (*Aporia crataegi*).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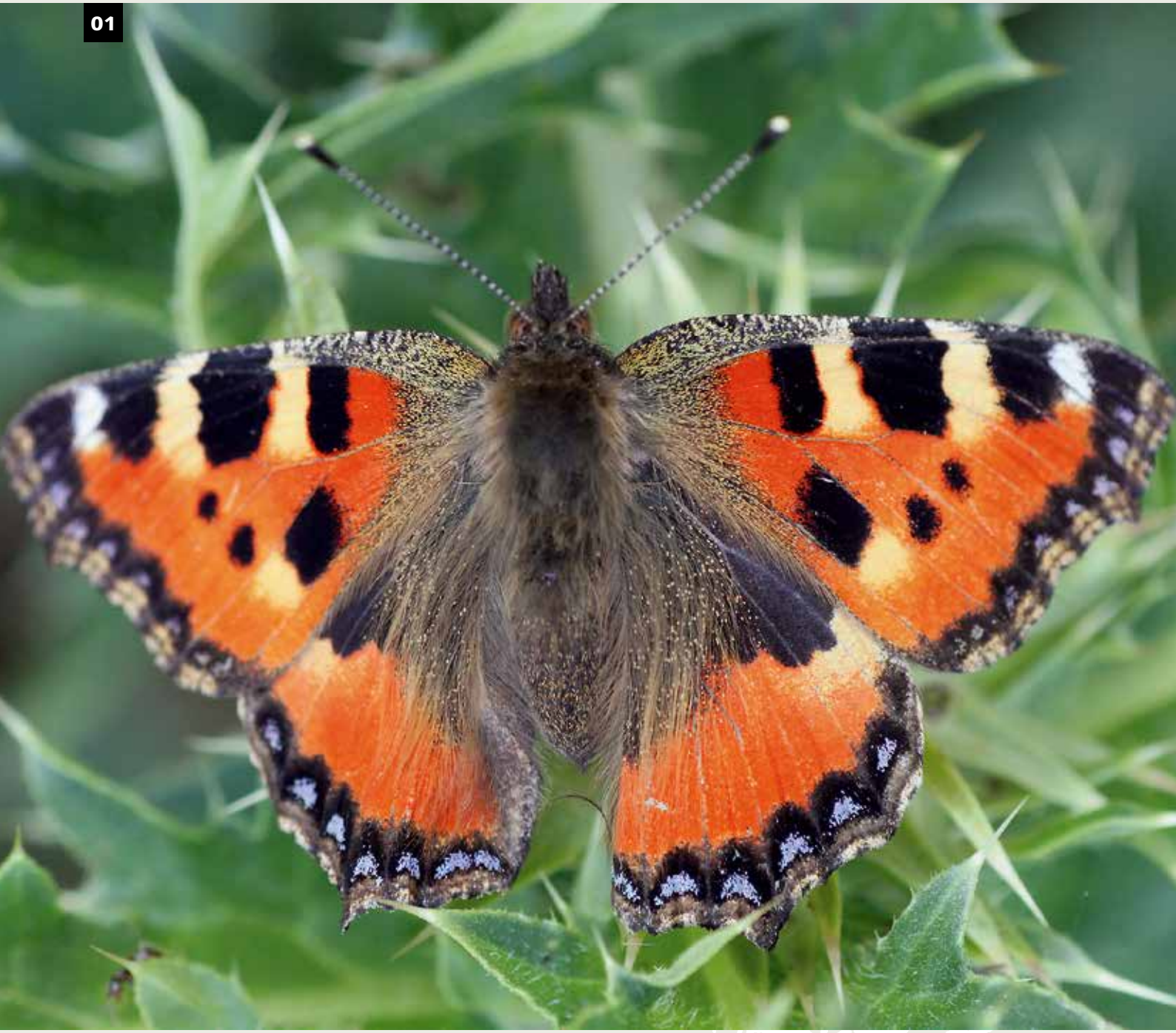
Perfect perfumes

Pheromones are scents that help male and female animals locate each other. This chemical communication is important in moth species, with females using pheromones to attract males.

01, 02, 03 The small copper (*Lycaena phlaeas*) belongs to the blue family (*Lycaenidae*). It prefers open landscapes and occurs frequently in mineral extraction sites. Its larvae feed on sorrel species.

04 Red sorrel (*Rumex acetosella*), the food plant of small copper caterpillars, is an indicator of nutrient-poor soils and is often associated with quarries and gravel pits.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01 The small tortoiseshell (*Aglais urticae*) is a common and widely distributed butterfly species.

02 Small tortoiseshell (*Aglais urticae*) caterpillars eat stinging nettles (*Urtica dioica*).

Many insects lay their eggs directly into the soil. Some species like grasshoppers or digger wasps place their eggs there directly with their ovipositors. Many beetles dig a cavity in the soil. Some butterflies, and many dragonflies and grasshoppers as well, lay their eggs into plant stems, moss, bark, or dead wood or attach them to the outside of plants.

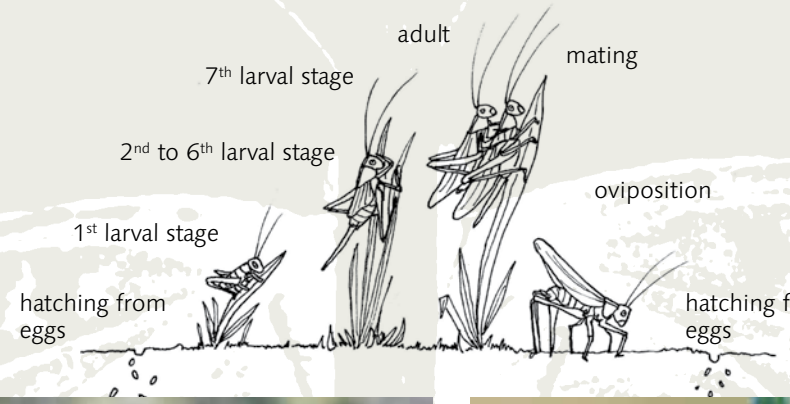
For oviposition, many insect species need loose soil and sparse vegetation in order to be able to reach open soil areas with favourable microclimatic conditions.

01 The chirping of field crickets (*Gryllus campestris*) from meadows and margins of fields is a familiar sound for many people. The specimen in this picture is a female. This can be told from the long ovipositor at the tip of its abdomen.

02 The female of the saw-tailed bush cricket (*Barbitistes serricauda*) bears a sabre-shaped ovipositor.

Example for hemimetabolism

(incomplete metamorphosis): life cycle of a grasshopper



03

03 The female small gold grasshopper (*Euthystira brachyptera*) lays its eggs in a special fashion by glueing its egg clutches to leaves which it then folds around to protect them, usually 20 to 25 centimeters high on the plant stem.

Metamorphosis

The transformation of larvae to adult animals is called **metamorphosis**. This term is used for animals whose juvenile and adult forms are very different; amphibians are a typical example. Two types of metamorphosis are distinguished:

Hemimetabolism – incomplete metamorphosis

When the larvae of grasshoppers, true bugs or cicadas hatch from their eggs, they resemble miniature versions of their parents, although they are not yet mature; they lack wing buds and fully developed sexual organs. During their development, each larval stage (**instar** in zoology) is more similar to the adult insect (**imagoe**). This stepwise tranformation with each molting is called **hemimetabolism**.

Holometabolism – complete metamorphosis

In holometabolic insects (including butterflies, flies, bees, wasps, ants and all beetles), the transformation of the final instar to the imagoe happens within the **pupa**. This is called complete metamorphosis or **holometabolism**. The final instar larva develops into the pupa. Some lepidopterans produce fine silk threads and weave a sturdy cocoon – an excellent protection for the developing imagoe. However, there are also pupae with very thin walls that can twitch and even move.

During metamorphosis, the caterpillar organs within the pupa are reorganised into butterfly organs. At the end of the process, a complete butterfly is ready to hatch from the pupa.

01 The shed skin of the final instar of a new forest cicada (*Cicadetta montana*), a hemimetabolic insect.

02 The shed skin of a grasshopper, another hemimetabolic insect.

Molting in insect larvae

Insect larvae eat in order to grow and develop. However, their exoskeleton is made of chitin, – a tough substance that acts like armour, with rigid plates connected by flexible ligaments – that cannot expand. So, as the larva grows, this armour has to be replaced with a larger one several times. The old skin cracks open and is shed – a process called molting. The new skin is still soft at first, but hardens once in contact with the air. Sometimes the molted skins – called exuviae – can be found dangling in the vegetation. It is important to know that once they are at the imagoe stage, insects do not grow any more and therefore stop molting.

The very hungry caterpillar – baby food for insects

Once insects have hatched from their eggs as tiny larvae, off they go: the big feast. Caterpillars do nothing but munch away all day. Therefore, they grow very fast and have to molt often. Some insect species only feed as larvae, because as imagoes they are busy exclusively with reproductive activities. This means that they have to store all the energy that they will later need as adults during the larval phase.

Some caterpillars exhibit warning colours, to show predators that they taste horrible. As caterpillars cannot move fast, this is their only defense strategy.

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01 Tropical caterpillars are often very brightly coloured ...

02 ...as are some European caterpillars, such as this swallowtail (*Papilio machaon*).

03, 04 Or take this spurge hawk-moth (*Hyles euphorbia*). It devours poisonous spurge and accumulates the poisonous compounds in order to become inedible.

05 Some caterpillars protect themselves with poisonous hairs, like this garden tiger moth caterpillar (*Arctia caja*).


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01, 02 In most bee species, every female takes care of its own offspring. Many species build their nests in the soil, like this leafcutter bee species (*Megachile circumcincta*, upper photo) and this sweat bee species (*Lasioglossum marginatum*) (below).

03 These paper wasps (*Polystes bischoffi*) are building their nest.

Diligent parents – brood care in hymenopterans

Bees, wasps, and ants are all hymenopterans. Most hymenopteran species have developed sophisticated brood care behaviour. Many species deposit their eggs in specifically designed structures together with a sufficient food supply for the larvae. Others live in highly organised societies where specialised workers take care of the brood. The larvae are fed and the colonies are defended fiercely.

Life on the road – dispersal and isolation

Many insects are very mobile and cover large distances during their life time. A range of species such as locusts and some butterfly species are famous for mass migrations.

Some butterflies typical in temperate zones – such as painted ladies (Vanessa cardui) or red admirals (Vanessa atalanta) – do not survive the cold winters. Nevertheless they are among the most widespread and popular butterflies. How is this possible?

Every spring and summer many butterflies from the Mediterranean and Africa migrate to central Europe where they propagate, with their offspring making the return journey southwards across the Alps in the autumn. In the following year, their successors will fly back northwards again. Some butterflies that live permanently in one biogeographic region also have the ability to disperse, but on a smaller scale.

01 The red admiral (*Vanessa atalanta*) is a well-known migratory butterfly.

02 Desert locusts (*Schistocerca gregaria*) continue to cause crop devastations in Africa.

Locusts

There are ten grasshopper species referred to as "migratory locusts".

They share a common trait by occuring in two different forms: in the **solitary phase**, they are harmless, stationary, and their numbers are low, whereas in the **gregarious phase**, this changes drastically. The two forms look so different that in the past they have often been falsely identified as being of two individual species.

Taking cue from certain environmental conditions, many solitary individuals meet in one place and a transformation to the gregarious form is triggered. These animals are much more active and act as a cohesive group. Finally, they all leave their habitat and begin a mass migration.

In the Middle Ages, the migratory locust (Locusta migratoria) caused devastating plagues. In Europe today, habitats for the solitary form, such as the alluvial plains of the lower Danube, have become so rare that the species is almost extinct in Europe and the gregarious phase has not been recorded for a long time. This is not the case in many African countries, where locusts, especially the desert locust (Schistocerca gregaria), can devastate arable crops. A single swarm can consist of up to one billion individuals, causing immense agricultural losses. In North America locusts continue to cause crop losses. Nowadays, locust swarms can be kept under control with chemical pesticides or biopesticides.

World wide butterfly migration

In the tropics there are more than 200 migrating butterfly species. In other parts of the world this phenomenon occurs as well. The journey of the monarch butterfly (*Danaus plexippus*) from North America to Mexico is the most famous example, with individuals travelling distances of more than 3,000 kilometers.

02

Habitats in quarries and gravel pits

Habitats in quarries and gravel pits

Ideal insect habitats are diverse, such as extensive meadows, pastures, field margins, bushes, forest edges. Roadsides and clearings can be significant as well. Some species colonise gravel and unconsolidated sediments. The general rule is simple: higher habitat diversity means higher species diversity. Transition zones between low and high vegetation are particularly species-rich. Here, both thermophile species and species prefering shadier conditions find their perfect place. Finding the perfect microclimate is of great importance for many species.

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01 Bees – like this mining bee (*Andrena haemorrhoa*) – need specific substrate for oviposition, e.g. dead wood, open soil, or sand faces.

02 Many mineral extraction sites harbour mosaics of water, copses, and areas of bare ground.

03 The Italian locust (*Calliptamus italicus*) prefers warm, very dry habitats and may also occur in mineral extraction sites.

Life in the water – shallow pools and deep ponds

Some insects depend on water during their life cycle. True water bugs spend their whole life in the water, whereas dragonflies, caddisflies, and alderflies spend only their larval phase within aquatic habitats. True water bugs, such as backswimmers or water stick insects, spend their whole "childhood" and most of their adult stage in the water, where they are lurking for prey. True water bugs, however, are also capable of flying on the quest for new habitats.

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The aquatic larval phase of dragonflies takes from just a few weeks to several years. The last molting, when the larva metamorphises to the adult insect, takes place on the shoreline. The adult insect will then return to the water merely for mating and oviposition.

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01 In quarries and gravel pits new waterbodies are created during excavation.

02 The water stick insect (*Ranatra linearis*) is a predatory true water bug. It lies in ambush for its prey and uses its breathing tube to reach the water's surface for oxygen. With its long hooked front legs it seizes aquatic beetles, backswimmers, and other insects.

03 Damselfly larvae, such as this migrant spreadwing (*Lestes barbarus*), live under water and use their tail appendages as gills.

04 The adult migrant spreadwing is just as intricate as its larva.

05 In shallow waters, ponds, and lakes, abundant insect life may develop. Their biomass is a crucial food source for frogs and some waterfowl.

Wetland creation

In many mineral extraction sites, gravel pit lakes, ponds, or shallow pools are created during exploitation. In order for them to become high quality habitats, the following advice should be observed.

To provide opportunities for many different insect species, a mosaic of freshly created, unplanted ponds and older waters with rich marginal vegetation is perfect. Here, both light-demanding and plant inhabiting insects may find their proper niches. It is a good idea to create new waters every couple of years. They should always have shallow shore zones and rolling shore lines. This creates shoal inundation zones and small bays which are of particular ecological value. In small waterbodies the introduction of fish should be avoided as they feed on dragonfly larvae and other water dwellers such as tadpoles or newt larvae, reducing the overall species richness. Water plants should not be introduced in order to allow native plants to move in spontaneously.

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01 Temporarily flooded inundation zones in mineral extraction sites are often very valuable habitats.

02 A typical species of wet meadows and hydrophilous tall herb fringe communities: the short winged conehead (*Conocephalus dorsalis*).

03 Tall herbs like purple loosestrife (*Lythrum salicaria*) ornament shore zones and attract flower visitors.

04 The spotted darter (*Sympetrum depressiusculum*) is a rare dragonfly species that may sometimes occur in flooded areas of gravel pits.

05 An Essex skipper or European skipper (*Thymelicus lineola*) takes a rest on rush flowers.

Bare ground and resilient creatures

It may seem strange at first sight, but it is true: bare ground is an important habitat for many rare specialist species. Sparsely vegetated gravel, sand, loam or clay plains – often resembling moonscapes – are characterised by warm micro climates and low spatial resistance – good prerequisites for many insect species. Such sites may host diverse beetle, bee, and grasshopper species.

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01 The wall brown (*Lasiommata megera*) prefers dry and warm sites and can be found on stony slopes.

02 Goldmoss stonecrop (*Sedum acre*) grows on nutrient poor soils and feels at home in many mineral extraction sites.

03 Green tiger beetles (*Cicindela campestris*) require sparsely vegetated soil.

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01 The rare red winged grasshopper (*Oedipoda germanica*) prefers weakly vegetated, well-insolated slopes, rocks, or dry meadows. Habitat loss has led to a dramatic decline of this species. It can find such optimal habitats in mineral extraction sites.

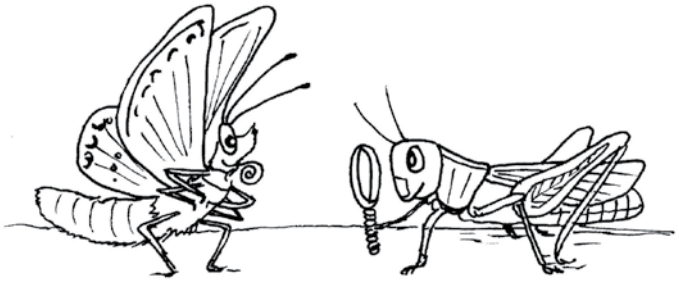
02 Nomad bees (genus *Nomada*) live as parasites in the nests of sand bees. They are directly dependent on their presence: No sand bees, no nomad bees.

03 The striped earwig (*Lapidura riparia*) prefers moist, sandy soils.

04 Sparsely vegetated gravel in a gravel pit.

05 The larvae of antlions excavate conical pit-traps in sand or loose soil. They half bury themselves at the bottom of these traps and wait for prey. Once a small insect inadvertently falls into the pit-trap the antlion larvae flicks loose sand at it, causing it to slide down the slope where it is grabbed and sucked dry by the huge mandibles of the larvae. These pit-traps belong to the larvae of *Euroleon nostras*.

06 Adult *Euroleon nostras* antlions resemble damselflies. Like most antlions, this species prefers dry and warm sites.



In troughs and depressions on loamy or clay substrates, flooded areas and small pools may develop. These can provide suitable habitats for diverse water insects such as dragonflies or water beetles.

01 On dry ruderal sites and in semi-natural dry meadows – also within quarries and gravel pits – the Queen of Spain fritillary (*Issoria lathonia*) may be found. The undersides of its wings bear large mother-of-pearl spots.

02 Sparsely vegetated, loamy soil surrounding a flooded former gravel pit.

03 The slender ground hopper (*Tetrix subulata*) prefers moist gravel or loam soils.

04 The long-winged grasshopper (*Aiolopus thalassinus*) lives in temporarily moist to wet, nutrient-poor habitats with only patchy vegetation.

05 The ground beetle *Nebria livida* with its conspicuous colour pattern inhabitats shore zones.

Colourful semi-natural dry meadows and species-rich grasslands

Meadows on nutrient-poor soils support considerable species richness. Just like in a tropical rainforest – but shrunk to a much smaller scale – this habitat is structured in a layered fashion. At the bottom mosses and small flowering plants prevail, the next level is characterised by low grasses and herbs, the following by taller herbs with grass spikes / heads towering above. The different plants on each level are in turn inhabited by different animals.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01 Flowering herbs in meadows are important suppliers of nectar and pollen for bees.

02 Butterflies and grasshoppers share the habitat provided by flowering meadows with bees, cicadas, hoverflies, and many other insects. Grasses and herbs, nectar and pollen serve as food sources.

03 A green-underside blue (*Glaucopsyche alexis*) is sitting on a quaking-grass flower (*Briza media*).

Wildflower meadows and their role for species protection

Wildflower meadows on nutrient-poor soils are very important for nature conservation because of the high biodiversity they harbour. However, these valuable habitats have suffered great declines caused by intensive land-use. Grasslands have been tilled and re-sown for arable production, or fertilised so strongly that a few vigourous grasses and plants out-compete out all the other species. This degraded landscape offers little biodiversity value, and results in the loss of habitat for most insects and many other animals.

Typical meadow herbs and grasses do not only tolerate regular cutting or grazing, they even benefit from this treatment which enables them to stay competitive. Once management measures – for example mowing or grazing – are stopped, these typical meadow plant species are soon replaced by shrubs and trees.

01 Grassland with oxeye daisies (*Leucanthemum ircutianum*) at a gravel pit lake.

02 Many quarries offer vast space for the creation of species-rich grassland on nutrient-poor soils.

03 A heath fritillary (*Melitaea athalia*) sitting on a round-headed rampion flower (*Phyteuma orbiculare*).

04 Glanville fritillary (*Melitaea cinxia*) from a site in eastern Germany.

On very poor soils, depending on the substrate, sandy or calcareous semi-natural dry meadows develop. This habitat type is preferred by the heath fritillary (*Melitaea athalia*), a species which is frequently found at mineral extraction sites. A much less frequent visitor is the Glanville fritillary (*Melitaea cinxia*).

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Creation and management of grassland

Meadows, pastures, and semi-natural dry meadows are termed as grasslands. They depend on regular management, for example by grazing or mowing, to prevent the growth of woody plants and to halt the natural sucession to woodland. Species-rich meadows can be created by sowing wild flower seeds, seeds collected from hay, or by "inoculation" with grass clippings. The soil should be prepared prior to seeding by ploughing and harrowing.

Dependent on its productivity, the grassland can be mowed once or twice per year and the hay removed. The best times for mowing in central Europe are usually end of June and August/September. Alternatively, grazing livestock can be used to keep the grassland open. However, pasturing periods must be short and with prescribed breaks between them. Permanent pasturing leads to high levels of nutrients because of manure which causes a loss of plant species diversity. Sheep and donkeys are particularly favourable for the management of grassland on rather nutrient-poor sites. Meadows and pastures with progressing scrub succession profit from grazing by goats and cattle.

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01 Sandy grasslands shelter rare light-demanding plants …

02 … such as sheep's bit scabious (*Jasione montana*), pictured above with a visiting green-veined white (*Pieris napi*).

03, 04 Sandy grasslands and other grasslands on nutrient-poor sites offer suitable habitats for mottled grasshoppers (*Myrmeleotettix maculatus*) and woodland grasshoppers (*Omocestus rufipes*).

05 The violet fritillary (*Boloria dia*) lives in semi-natural dry meadows.


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01 The larvae of Reverdin's blue (*Plebeius argyrognomon*) feed on purple crown vetch (*Securigera varia*). This species occurs mostly in underused semi-natural dry grasslands and fringe communities adjacent to forests.

02 The sweat bee species *Halictus scabiosae* builds its nests in sparsely vegetated soil and collects pollen from only a few plant species.

03 A carniolan burnet (*Zygaena carniolica*) sitting on a brown knapweed flower (*Centaurea jacea*).

04 A butterfly look-alike, but from a completely different order: the owly sulphur (*Libelloides coccajus*) is an owl fly that belongs to the net-winged insect family. It lives in very warm habitats. The larvae are predators that hunt for other insects on the ground.

Flower-rich field margins and tall vegetation

Field margins and forest edges with flowering tall herbs as well as fallow meadows are important refuges for numerous insects. South-facing slopes and enbankments are especially species rich.

On the previous pages, the high nature value of meadows and pastures and the importance of their regular management has been pointed out. So shouldn't fallows be an absolute no-go? Not at all, as will be explained in the following example.

There are all kinds of different reproductive behaviours in the insect group. Species that lay their eggs into the soil are dependent on enough sunlight reaching and warming up the oviposition site – this means that regular mowing and not too dense vegetation is exactly what they need. However, other species, such as grasshoppers and some butterfly species, which lay their eggs on stems of grasses and other plants, are at risk of being destroyed when the grass is cut for hay. So these species profit when a meadow is left unmanaged. Therefore, a mosaic of managed and unmanaged meadows or very extensively used grasslands is ideal. Alternatively, strips of taller grass can be left when mowing meadows.

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01 Tall forbs at a gravel pit lake.

02 The gatekeeper, sometimes called the hedge brown (*Pyronia tithonus*) is a species that likes forest edges and poor grasslands.

01, 02 The comma (*Polygonia c-album*) and the chequered skipper (*Carterocephalus palaemon*) occur frequently in tall vegetation and along forest edges.

03 The Jersey tiger (*Euplagia quadripunctaria*) moth prefers the warm habitats that are associated with quarries. It can often be found sucking nectar on hemp-agrimony (*Eupatorium cannabinum*). In Europe the Jersey tiger moth is protected as a species listed in annex II of the Habitat Directive.


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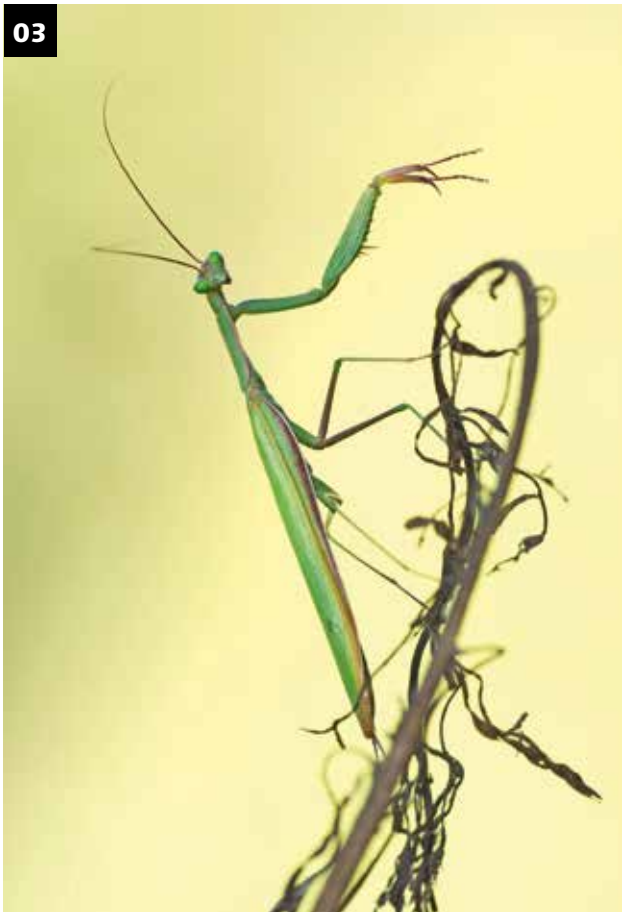
Nectar and pollen from tall herbs are a food source for flower visitors. They are particularly important for bees, butterflies, and hoverflies, but longhorn beetles and true bugs feed on what the showy flowers offer, too. Concerts delivered by sickle-bearing bush-crickets add to the flair of such vegetation, while such a habitat type also provides opportunities for praying mantises.


03

01 The six-belted clearwing (*Bembecia ichneumoniformis*) lives in dry tall herb vegetation. Its caterpillars feed on the roots of diverse plants of the legume family (Fabaceae). Caterpillars of other clearwing species (Sesiidae) live in woody plants. The wasp-like appearance of the six-belted clearwing is an excellent example of mimicry, when a harmless animal imitates a noxious or stinging animal in order to deceive predators. Clearwings belong to the lepidoptera order.

02 A small skipper (*Thymelicus sylvestris*) on blueweed (*Echium vulgare*).

03 The praying mantis (*Mantis religiosa*) is an impressive insect. It sits well camouflaged on a plant, ready to seize its prey. This fierce relative of grasshoppers prefers the sunny spots of tall forbs along forest edges.

04 A bee on a common tansy (*Tanacetum vulgare*).

Creation and management of tall forb vegetation

In contrast to hay meadows, slopes with many flowering herbs and tall forb vegetation are usually cut only every second or third year. Grasses and herbs establish spontaneously at suitable sites; periodic mowing prevents the establishment of shrubbery and trees. If desired, the development of these plant communities can be accelerated by sowing seeds of native tall forbs such as – in central Europe – fireweed (*Epilobium angustifolium*) or common tansy (*Tanacetum vulgare*).

Shrubs, copses, and forest edges

Small copses, shrubs, and individual trees are important habitats for many insects; most valuable are the south-facing, species-rich and layered forest edges. They do not only offer abundant food, but are also attractive rendez-vous sites for reproduction.

01 The capricorn beetle (*Cerambyx scopolii*) is a longhorn beetle species which requires coarse woody debris. Dead trees are needed as larval habitats.

02 A bee beetle (*Trichius fasciatus*) perching on a privet flower.

03 Copses, forest edges, and single trees are important habitats for animals – which are commonly found in mineral extraction sites.

Dead wood: a creepy-crawly cornucopia!

Dead and decaying trees are important habitats for specialised insects such as longhorn beetles and other beetles. The "worm holes" and burrows produced by the beetle larvae dwelling and growing in the dead wood serve later as brood chambers for bees.

The violet carpenter bee (*Xylocopa violacea*) is a big bee species that makes its nests in dead wood. Therefore, dying and dead trees should be preserved wherever possible. The larvae living in the dead wood are also food for woodpeckers. The tree cavities they produce are later re-used by a whole array of other vertebrates.

03

01 The silver-washed fritillary (*Argynnis paphia*) is a common butterfly. The species prefers forests, where the butterflies prefer sunny areas such as clearings, forest track margins, and forest edges.

02 A diverse quarry landscape.

03 The impressive stag beetle (*Lucanus cervus*) needs old oak stands for successful reproduction.

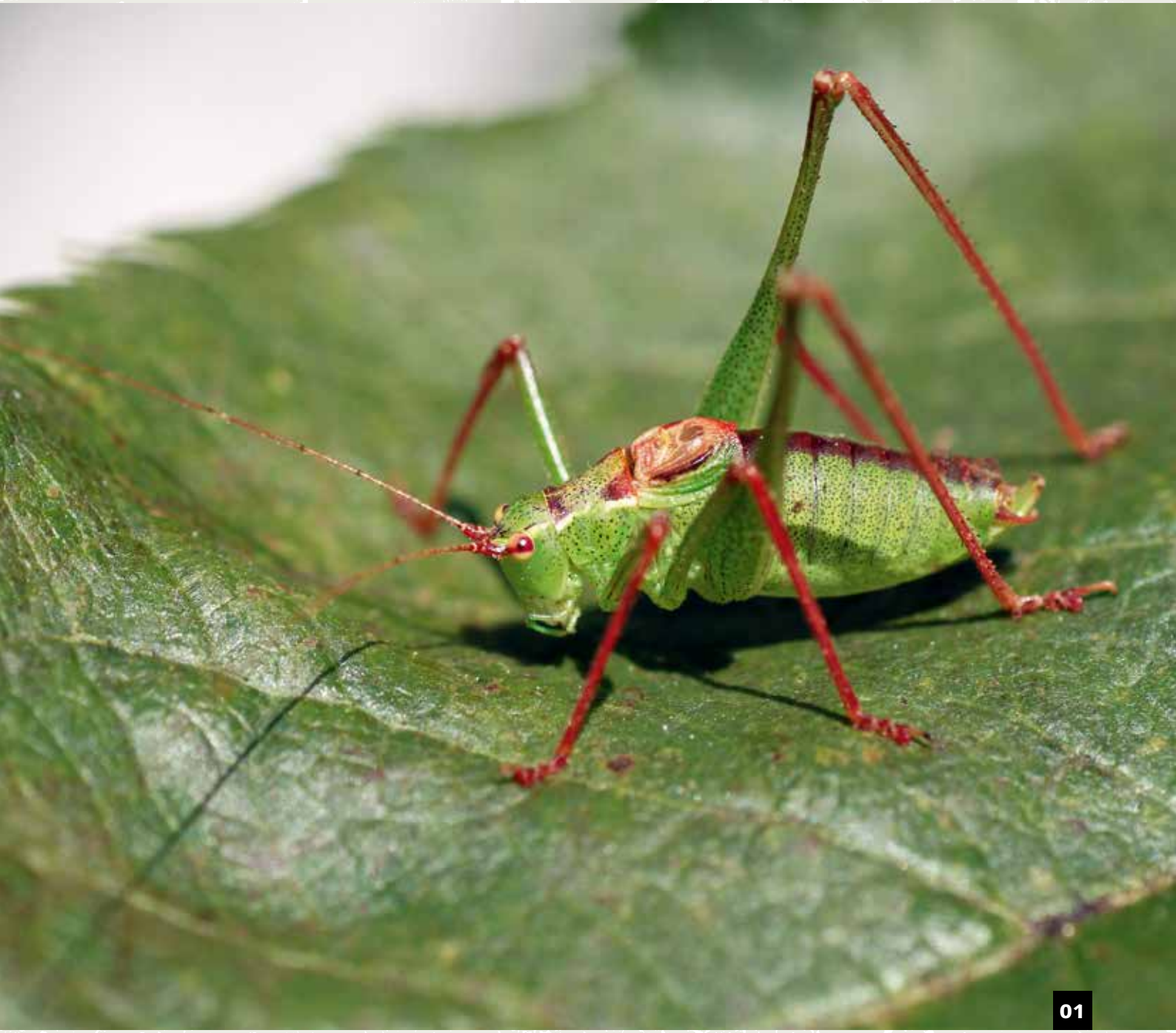
Native shrubs in mineral extraction sites

In central Europe woody plants take over almost all uncultivated sites during the course of natural vegetation succession. They establish completely spontaneously from airborne seeds, seeds from bird droppings, or seeds stored as winter supplies by squirrels or jays. These natural processes account for the establishment of a group of woody plant species adapted to the given site and soil conditions.

When planting woody plants, only native species of regional provenance should be employed. Exotic trees or ornamental shrubs should be omitted. Their flowers often produce no nectar at all, or native insects cannot reach the nectar inside the flowers.

Trees and shrubs are colonised by many insects – among others, grasshoppers, some caterpillars, and many beetles – feeding on leaves, buds, or dead wood. In addition, many flower visitors feed on nectar and pollen supplied by flowering shrubs such as common dogwood, hawthorn, or guelder-rose.

03



01

01 The speckled bush cricket (*Leptophyes puncatissima*) lives at the edges of forests and copses.

02, 03 The speckled wood butterfly (*Pararge aegeria*) and the rare ilex hairstreak (*Satyrium ilicis*) are found inhabiting sparce forests.

Nature protection in quarries and gravel pits

Nature protection in quarries and gravel pits

Quarries and gravel pits are significant retreats for numerous insect species. Many insect species are threatened and red listed – the result of the destruction and fragmentation of natural areas through increased urbanisation and unsustainable agricultural practices. Vast monocultures are treated with herbicides, depriving insects of their food sources. Agricultural pest management kills not only the "pests" but also – unintentionally – many other non-target insects. Huge modern machinery demands big, uniform arable fields, which has led to the loss of many field boundary features, for example trees, hedgerows, and waterbodies.

In the European Union a set of species are protected by the Habitats Directive. This legal framework aims to protect some 220 habitats and approximately 1,000 species listed in the Directive's Annexes. Many positive examples have shown that mineral extraction and species protection successfully work side by side.


01

Habitat fragmentation

The fragmentation of landscapes by roads, settlements, and inhospitable monocultures leads to the separation of insect populations. Very small and flightless species are most affected. The exchange of individuals – and thus so-called gene flow – is inhibited or becomes even impossible. Subpopulations may become extinct. This effect is called **habitat fragmentation**. Richly structured, diverse mineral extraction sites may serve as valuable stepping stones between existing habitat patches which alleviate this effect.

01 Rock face in a quarry.

02 Quarries and gravel pits can be important secondary habitats for insects in intensive agricultural landscapes, when they are managed soundly. Habitats on sparsely vegetated, nutrient-poor ground have become extremely rare in modern landscapes.

Natura 2000

Natura 2000 is a network of nature protection areas in the territory of the European Union. It is made up of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the Habitats Directive and Birds Directive. The network includes both terrestrial and marine sites (Marine Protected Areas: MPAs).

Natura 2000's aim is to preserve and create habitat refuges for plant and animal species for which member states and regions have special responsibility. A set of insect species of particular conservation concern is listed in Annexes II and/or IV of the Habitats Directive.

01, 02 Scarce large blue (*Maculinea teleius*) and scarce heath (*Coenonympha hero*) are two representatives of butterflies listed in Annex II of the European Habitats Directive. This means that the designation of Special Areas of Conservation for them is required. Apart from this legal framework of the European Union, most countries have national laws guaranteeing special protection for certain species.

03 Colourful tropical insects, such as this jewel beetle (Buprestidae) from Peru, are threatened by commercial insect collectors.

The plight of beauty – species collection

The stunning beauty of butterflies has long triggered a strong collector's passion. Not only researchers, but also hobby entomologists have decimated the local populations of certain species in Europe and elsewhere. Today the collection of butterflies and other insects in Europe is regulated and restricted to scientific purposes. In many countries in tropical or subtropical regions, however, especially big and showy insects are still caught in great numbers. These are then prepared and sold as souvenirs for commercial purposes. This leads to strong declines in many insect populations even nowadays.


03

Bibliography

BAUR, B., H. BAUR, C. ROESTI & D. ROESTI (2006): Die Heuschrecken der Schweiz. Haupt, Bern.

BELLMANN, H. (1993): Heuschrecken beobachten, bestimmen. Naturbuch Verlag, Augsburg.

BELLMANN, H. (2005): Bienen, Wespen, Ameisen. Franckh-Kosmos, Stuttgart.

BRÄU, M., R. BOLZ, H. KOLBECK, A. NUNNER, J. VOITH & W. WOLF (2013): Tagfalter in Bayern. Ulmer, Stuttgart.

DETZEL, P. (1998): Die Heuschrecken Baden-Württembergs. Ulmer, Stuttgart.

EBERT, G. & E. RENNWALD (Hrsg.) (1991): Die Schmetterlinge Baden-Württembergs. Band 1, Band 2, Tagfalter I und Tagfalter II. Ulmer, Stuttgart.

EBERT, G. (Hrsg.) (1994, 1997, 1998, 2001, 2003, 2005): Die Schmetterlinge Baden-Württembergs. Band 3 – 10, Nachtfalter I – Nachtfalter VII, Ergänzungsband. Ulmer, Stuttgart.

GRABOW, K. (2000): Farbatlas Süßwasserfauna Wirbellose. Ulmer, Stuttgart.

INGRISCH, S. & G. KÖHLER (1998): Die Heuschrecken Mitteleuropas. Westarp-Wissenschaften, Magdeburg.

INULA (2011): Dragonflies in quarries and gravel pits. – Biodiversity in mineral extraction sites, volume 1. Editor: M. Rademacher, Global Management Biodiversity and Natural Resources, HeidelbergCement, 96 pages.

INULA (2012): Orchids in quarries and gravel pits. – Colourful queens of the plant kingdom. – Biodiversity in mineral extraction sites, volume 2. Editor: M. Rademacher, Global Management Biodiversity and Natural Resources, HeidelbergCement, 96 pages.

INULA (2013): Birds in quarries and gravel pits - Flying gemstones and swift hunters. – Biodiversity in mineral extraction sites, volume 3. Editor: M. Rademacher, Global Management Biodiversity and Natural Resources, HeidelbergCement, 96 pages.

INULA (2014): Amphibians and reptiles in quarries and gravel pits. – Wanderers between the elements. – Biodiversity in mineral extraction sites, volume 4. Editor: M. Rademacher, Global Management Biodiversity and Natural Resources, HeidelbergCement, 96 pages.

INULA (2015): Biodiversity Management in quarries and gravel pits. – Biodiversity in mineral extraction sites, volume 5. Editor: M. Rademacher, Biodiversity & Natural Resources, Fachhochschule Bingen, 92 pages.

MÜLLER, A., A. KREBS & F. AMIET (1997): Bienen – Mitteleuropäische Gattungen, Lebensweise, Beobachtung. Naturbuch Verlag, Augsburg.

NÖTZOLD, R. (1993): Bestimmungsschlüssel für Käferfamilien. 2. überarb. Aufl., Goecke & Evers, Krefeld.

PRO NATURA – SCHWEIZERISCHER BUND FÜR NATURSCHUTZ (Hrsg.) (1994, 1997, 2000): Schmetterlinge und ihre Lebensräume. – Arten, Gefährdung, Schutz. Schweiz und angrenzende Gebiete. Band 1-3. Fotorotar AG, Egg.

SCHLUMPRECHT, H. & G. WAEBER (2003): Heuschrecken in Bayern. Ulmer, Stuttgart.

SETTELE, J., R. FELDMANN & R. REINHARDT (1999): Die Tagfalter Deutschlands – Ein Handbuch für Freilandökologen, Umweltplaner und Naturschützer. Ulmer, Stuttgart.

TOLMAN, T. & R. LEWINGTON (1997): Field Guide Butterflies of Britain and Europe. HarperCollins Publishers, London.

WACHMANN, E. (1989): Wanzen – beobachten, kennenlernen. Neumann-Neudamm, Melsungen.

WACHMANN, E. & C. SAURE (1997): Netzflügler, Schlamm- und Kamelhalsfliegen. Beobachtung, Lebensweise. Naturbuch Verlag, Augsburg.

WESTRICH, P. (1990): Die Wildbienen Baden-Württembergs, Band 1, Band 2. Ulmer, Stuttgart.

WILLNER, W. (2013): Taschenlexikon der Käfer Mitteleuropas – Die wichtigsten Arten im Porträt. Quelle & Meyer, Wiebelsheim.

ZAHRADNIK, J.(1985): Käfer Mittel- und Nordwesteuropas. Parey, Hamburg.

ZURBUCHEN, A. & A. MÜLLER (2012): Wildbienenschutz – Von der Wissenschaft zur Praxis. Haupt, Bern.

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