MANAGING AGGREGATES SITES FOR INVERTEBRATES – A BEST PRACTICE GUIDE

Aggregates sites present fantastic opportunities for habitat creation and site restoration projects that can contribute substantially to halting the loss of invertebrates and delivering UK Biodiversity Action Plan targets.

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FOREWORD

Conserving biodiversity – the variety of life on Earth – is one of the growing challenges of the 21st century. While it is well known that, if established in the wrong place, aggregate extraction sites can endanger wildlife, it is less widely appreciated that they can also contribute enormously to the conservation of biodiversity, not just in terms of a few trees and open space, but in terms of providing refuges and breeding sites for nationally and internationally endangered species.

Old quarries such as Thurlbear Quarrylands in Somerset are not only a riot of colour and life that provide valuable amenity for people, they can also support vitally important populations of rare and endangered bees, butterflies, beetles, spiders, moths and other invertebrates. Indeed, many of the UK's best nature conservation sites are old extraction sites.

Aggregates sites present fantastic opportunities for habitat creation and site restoration projects that can contribute substantially to halting the loss of invertebrates and delivering UK Biodiversity Action Plan targets. However, advice and information about the needs of endangered invertebrates has not been readily available to the aggregates industry, and invertebrates are rarely taken into account when decisions are made about the future of sites. In the worst cases, inappropriate restoration schemes and site management regimes (often characterised by invertebrate conservationists as top-soiling and tree-planting) have destroyed special invertebrate habitat and special species have been lost.

However, the evidence is clear, managers of aggregates sites want to help biodiversity on their sites and are hungry for information that will assist them in achieving this. Hence, the publication of "Managing Aggregates Sites for Invertebrates – a best practice guide" with support from Natural England through Defra's Aggregates Levy Sustainability Fund. The guide highlights best practice and sets out the principles for managing and restoring aggregate sites for invertebrate biodiversity: sometimes doing less achieves more.

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INTRODUCTION

The aggregates extraction industry can, and does, play an important role in nature conservation. Many of the UK's best wildlife sites are on old extraction sites (such as quarries), and as active sites come to the end of their working lives, they present great opportunities for creating habitats of high value for bees, butterflies, beetles, spiders and other invertebrates. A whole range of birds, plants, amphibians, reptiles and other wildlife can also benefit.

There are many circumstances where there can be a biodiversity gain by the activities of the mineral industry, positives rather than negatives, and perhaps none more so than for invertebrates.

There are two main ways in which the industry has a direct impact on wildlife. Firstly in the development of new sites for aggregate extraction; here attention is focused on what habitats and species are likely to be lost if extraction takes place. Secondly, where new opportunities for wildlife can be created as a result of the extraction process. The purpose of this guide is not to discuss the development of new sites, but to provide guidance on how to maximise the opportunities for wildlife through site restoration and the management of active sites.

Through careful planning aggregates sites can support an amazing diversity of invertebrates both during and after extraction activities. Habitat creation and site restoration projects have the potential to make a considerable contribution to conserving invertebrates and delivering UK Biodiversity Action Plan targets. There are many examples of good practice in site management and habitat creation; however, these are rarely focused on invertebrate conservation.
More can be done to maximise the benefits for invertebrate biodiversity. Managing for invertebrates is often a simpler, lower cost option, and can easily be incorporated into existing site restoration plans.

This best practice guide aims to highlight the contribution of the aggregates industry to invertebrate conservation, and to help site and estates managers, minerals planners and ecological consultants make the most of the biodiversity opportunities that aggregate sites present, with a focus on invertebrates. The guide is intended as a brief summary of some of the most important naturally regenerating habitats on aggregate sites and those habitats that for one reason or another have been neglected or under-appreciated in the past. Notes are also included on some of the habitats more commonly targeted by restoration plans. It is not intended as an exhaustive guide (that would be considerably longer than 24 pages!) but as a first point of reference. The guide is not a substitute for specialised ecological advice.

More detailed information on some of the topics discussed can be found on the Buglife website **www.buglife.org.uk**

Picture credits: front cover - Sand Pit in bloom © Peter Harvey; *Cerceris quinquefasciata* © Mike Edwards; this page - *Bombus humilis* © Sam Ashfield

CONSERVING BIODIVERSITY

Biodiversity is the variety of life on our planet. Much of the nature conservation work carried out in the UK is guided via the UK Biodiversity Action Plan (UKBAP). The UKBAP identifies over 1000 species and 65 habitats which are considered to be under threat or of particular conservation importance. BAP delivery is split into action plans for these Priority Species and Habitats (SAPs and HAPs) to guide the work required to address their decline. National BAP targets are translated into local action via the Local Biodiversity Action Plan (LBAP) process.

The aggregates industry has an important role to play in delivering national and local BAP targets for habitats and species.

Why conserve invertebrates?

Invertebrates are perhaps the group that has benefited the most from the activities of the aggregates industry, yet they are also the most neglected when it comes to aggregates planning and site management. If we are going to conserve biodiversity we must give invertebrates a higher profile. Over 65% of all species on the planet are invertebrates. There are more than 32,000 terrestrial and freshwater species in the UK alone - many of which are of conservation concern, including over 400 listed on the UKBAP.

In addition to the intrinsic need to prevent the extinction of species, invertebrates provide ecosystem services such as the pollination of crops and wildflowers, nutrient cycling, maintaining soil fertility, and are the food source of many birds, small mammals, reptiles and amphibians – many of which are also of conservation concern.

Planning for biodiversity

Conserving the UK's biodiversity is an essential pillar of sustainable development. National planning policy and legislation requires Government, planning authorities and the industry to further the conservation of biodiversity in their work. Sensitive management of aggregates sites and well-targeted habitat creation offers an opportunity to contribute to the conservation of biodiversity and enhance the industry's ability to operate in a truly sustainable manner.

The aggregates industry and planning authorities generally recognise their roles in conserving biodiversity and there are a number of excellent examples of BAP Priority habitat creation. We have started to progress beyond the 'off the peg' identikit restoration schemes with their amenity ponds and generic tree planting schemes that were common in the past. However, these sites only represent a fraction of what could be achieved, especially for invertebrate biodiversity.

Left: *The Brown-banded carder bee (Bombus humilis) was once widespread but has become increasingly restricted to quarries and brownfield sites.*

Why are aggregates sites good for invertebrates?

The extraction process itself creates useful invertebrate habitat, this can be enhanced or maintained through appropriate management. Intrinsic or naturally establishing features of extraction sites that are of value to invertebrate biodiversity include:

1. **Disturbance**
   The extraction process creates and maintains open patches of bare ground and early successional stages of vegetation – features which are increasingly rare in the wider countryside.

2. **Bare ground**
   Bare ground heats up quickly in the sun to provide ideal conditions for warmth-loving invertebrates. It also provides nesting sites for burrowing species.

3. **Abundant wildflowers**
   These provide nectar and pollen sources for bees and butterflies. A greater variety of plant species is likely to support a higher number of invertebrates.

4. **Delayed succession**
   Harsh environmental conditions such as dry, low-nutrient mineral soils can delay vegetation succession to closed grassland and scrub.

5. **Varied topography**
   Quarrying, filling, and other operations create a wide range of topographical features from the macro (e.g. sand cliffs) to the micro (e.g. wheel ruts).

6. **Water**
   Operations below the water table can create water bodies and opportunities for wetland habitats of high biodiversity potential to develop.

7. **Opportunity**
   Through appropriate habitat creation and restoration work aggregates sites offer a great opportunity to deliver UKBAP targets and other nature conservation goals.

Picture credit: right - *Bombus humilis* © Steven Falk

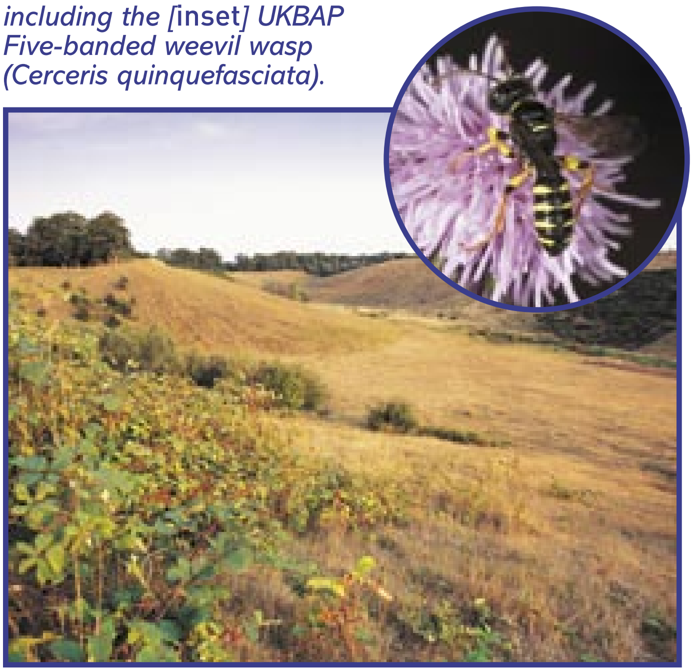
SITE RESTORATION

The potential for creating habitats of high potential for biodiversity through site restoration is great. However, the current state of knowledge of habitat creation techniques means that habitat creation cannot be a substitute for the ***in situ*** conservation of habitats and species. Irreplaceable wildlife sites should be protected from development.

Historically most site restoration has been to agricultural land, not wildlife habitat. There are, of course, exceptions – such as flooded sand and gravel workings which have become important sites for overwintering wildfowl and aquatic species; and other sites which have naturally regenerated or 'rewilded' into valuable wildlife sites with little or no management intervention. Over 600 Sites of Special Scientific Interest (SSSIs) are former aggregate or mineral workings, the majority of which are 'rewilded' sites where restoration has not taken place. An increased recognition of the potential of aggregate sites to contribute to national and local biodiversity objectives has led to more sites being restored to nature conservation.

The intensified use of the UK countryside has led to a gradual loss of semi-natural habitats. The remaining patches have become increasingly isolated and fragmented, and surrounded by hostile land uses. Aggregate site restoration provides an opportunity to address some of this loss by creating new habitats, and enlarging existing patches; and to re-instate habitat linkages, connecting remaining patches to form sustainable ecological networks.

Below: *Sandy Heath Quarry – the creation of a large scale heathland and acid grassland mosaic is contributing to local and national BAP targets. This site is known to support 26 rare and scarce invertebrates including the [*inset*] UKBAP Five-banded weevil wasp (Cerceris quinquefasciata).*



Some features of good site restoration:

1. **Habitat creation should be appropriate to location.** Factors to consider include:physical conditions on site (geology, hydrology, topography), previous site history (what existed prior to extraction or prior to previous intensive use), relationship to existing surrounding habitats.

2. **Linked to existing habitat.** Site restoration should aim to improve existing ecological networks. Habitat creation can enlarge existing habitat patches; create buffer zones from intensive land use around patches of high quality habitat; provide ecological linkages - reconnecting habitats and species populations, and helping to address habitat fragmentation and site isolation. Effective ecological networks may also play a part in safeguarding habitats and species against the impacts of climate change.

3. **Large scale.** Bigger is better – large habitat patches allow for habitat heterogeneity and mosaics, they are likely to support a greater range of species and at more viable population levels (including those which require large areas of habitat), they are easier to manage and are more sustainable in the long-term.

4. **Adequate funding.** Funding provision needs to be made for initial work as well as long-term management and monitoring.

5. **Clear objectives.** A clear vision for a site helps to maintain focus on delivering high quality habitat. Restoration plans should have clear links to local and national BAP targets.

6. **Small scale features.** Restoration schemes should not neglect small features of value to invertebrates and other wildlife. Small scale habitat features (e.g. patches of bare ground, banks and cliffs, ponds, ditches, seasonally wet areas) are easily incorporated within larger schemes and can add considerable biodiversity value.

7. **Working with nature.** Natural regeneration and natural processes of succession should be encouraged where appropriate.

8. **Flexibility.** Restoration plans should remain flexible enough to allow amendments should opportunities for further wildlife gain come to light, e.g. a particular species colonises or useful habitat develops.

9. **Biodiversity the priority.** The most effective schemes produce the right conditions for biodiversity to thrive and then fit amenity and other end uses within this context. These are often not in conflict with invertebrate conservation: invertebrate populations can sustain, and in some cases rely on, recreational disturbance.

Picture credits: left - *Cerceris quinquefasciata* © Mike Edwards; Sandy Heath Quarry © Andy Hay (rspb-images.com)

THE VALUE OF NATURAL REGENERATION

Some features of poor site restoration:

1. **Inappropriate habitats for the location.** Restoration should aim to create habitat which is suitable to the geology, hydrology and topography of the site, appropriate to the surrounding landscape, and can make a positive contribution to existing local habitat networks.

2. **Too many habitats.** As tempting as it is to try and include as many habitats as possible within a restoration scheme, larger blocks of fewer habitat types yield a better result for wildlife.

3. **Unsustainable schemes.** It is a waste of resources to create habitats that cannot be maintained in the long term. Habitats in need of ongoing management (e.g. heathland) need to be large enough to be managed effectively (e.g. grazed or cut), and provision must be made for local resources to enable management to continue in the long term.

4. **Failure to recognise and retain the existing or developing biodiversity interest of the site.** Wildlife will colonise a site throughout its active phase and valuable habitat can develop through natural regeneration where undisturbed. These naturally regenerating habitats are rare in the wider countryside and can support important populations of rare and scarce invertebrates. Nationally important invertebrate sites have been lost to the restoration process, even where the goal has been nature conservation.

5. **Too many end uses demanded for the site.** There are many examples of sites where biodiversity has been added as an afterthought, or as a poorly conceived 'add on' to agricultural or amenity use. The most effective schemes for biodiversity are those where the primary end use is nature conservation. However, through careful planning wildlife can be provided for alongside other end uses such as public amenity and conserving geodiversity.

A caveat. ***Habitat restoration techniques are often experimental and are constantly being developed and improved - those directed at invertebrates are perhaps the least tried and tested. The recommendations in this report are based on current ecological knowledge, and should not be regarded as the final word on managing sites for invertebrates – more a starting point to developing our knowledge further. Each restoration project should be regarded as an opportunity to learn more and share best practice.***

Above: *Land forming in the early stages of site restoration.*

The value of natural regeneration

There seems to be a perception amongst industry, minerals planning, and the general public that site restoration should be intensive and provide instant results. But nature takes time, and the best results for biodiversity are achieved when working with nature, not forcing it or attempting to leapfrog stages of habitat succession.

Natural regeneration from bare mineral soils can provide habitat of high ecological value, and which is often more appropriate and suited to the site. This is also a lower cost option; restoring a site by regrading slopes, adding topsoil, seeding or tree-planting requires considerable investment of time, effort and money. From a nature conservation perspective, there is no justification expending scarce resources on restoration unless the outcome is going to be significantly more advantageous for biodiversity than if a site is left to natural regeneration.

Of course, abandonment is not a realistic option - some restoration work and landforming may be necessary, for example to mitigate for health and safety risks. Nevertheless, quarry restoration should aim to retain 'untidy' features like cliffs, hummocks and hollows, and provide continuity of the early-successional habitat conditions for invertebrates at the same time as managing landscape and safety issues.

Where workings displace previously 'unimproved' soils, however, the saving of topsoil and its associated seed-bank has a place. Even here, the spreading of such soil should leave patches uncovered to promote habitat diversity. There may be cases where the use of seed is necessary, because of a need to establish cover quickly, or on isolated sites with no nearby seed source. If so use seed of local provenance which suits the site conditions – small areas of the site can be tested to determine the most suitable mix.

All sites are different, and there is often a case

Picture credit: right - © Nick Mott

TERRESTRIAL HABITATS – USEFUL FEATURES AND RESTORATION PRINCIPLES

for some ongoing management, perhaps to guide natural regeneration towards a target habitat, to control non-native or invasive plants, or where natural colonisation is unlikely to yield high quality results due to the isolation of a site. The key is to work with natural processes rather than forcing them.

Right: *Planting trees over flower-rich early successional vegetation damages useful invertebrate habitat and has a negative impact on biodiversity.*

Terrestrial habitats – useful features and restoration principles

The intrinsic invertebrate interest of aggregates sites is largely a result of disturbance created by the extraction process. Active operations provide bare ground and pioneer ecological conditions, with complex mosaics of other habitats that alone and in combination provide ideal conditions for a range of invertebrates.

Site restoration offers an opportunity to create new habitats and go some way to addressing historic habitat loss. In theory the range of habitats that can be created on aggregates sites is limitless. In practice, only a few options will actually be appropriate to a particular site. The following section concentrates on some of the important naturally establishing features and habitats, with notes on other terrestrial habitats often featured in habitat creation schemes.

Below: *In quarries and pits complex topography and varied vegetation structure provide a wide range of niches.*

a. *Limited scattered trees and scrub can provide useful foraging areas and habitat such as dead wood.*

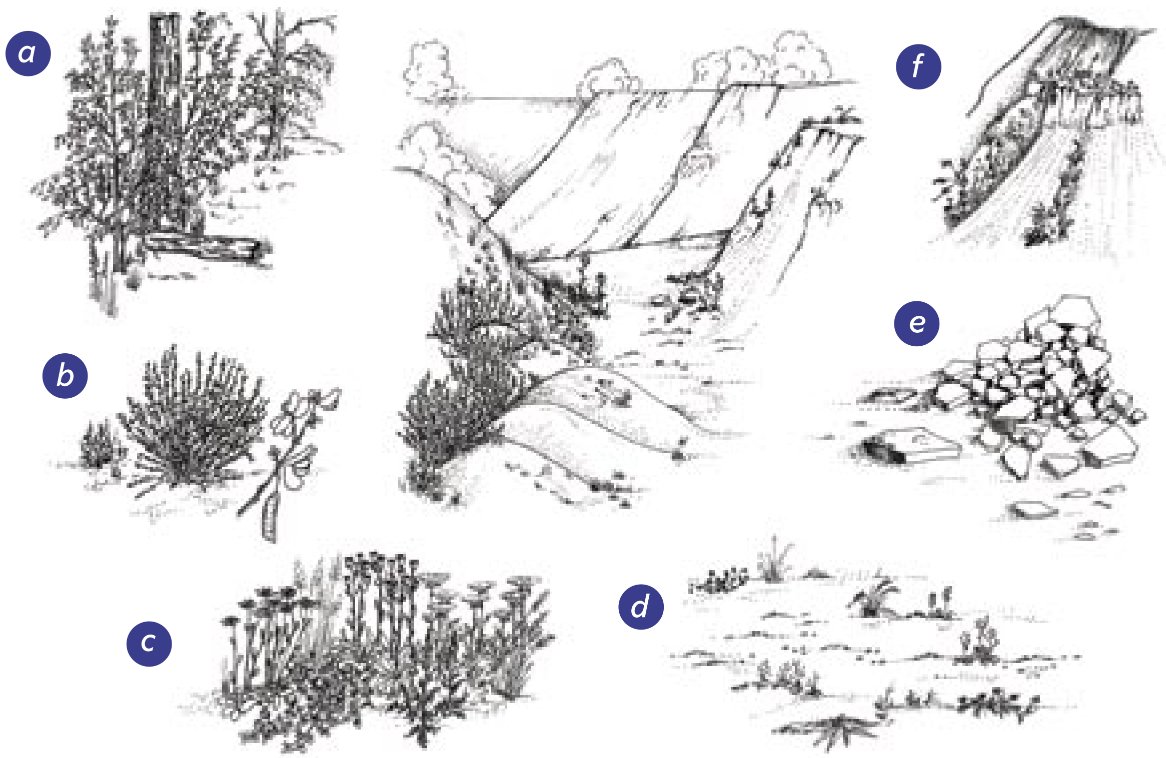
b. *Scrub plants such as broom and gorse can be an important source of nectar and pollen, and can support their own fauna.*

c. *Tall, flower-rich vegetation is a valuable nectar resource.*

d. *Sparsely-vegetated ground provides special conditions for ground nesting and warmth-loving species.*

e. *Piles of rubble and loose rocks provide habitat and shelter.*

f. *Bare cliffs and slopes provide valuable nesting sites for burrowing bees and wasps.*



Picture credits: right - tree planting © Andy Jukes; quarry illustration © Buglife/Peter Kirby

Topography and micro-habitats

Local topography is an important factor in the planning of habitat restoration or creation projects, in particular with reference to invertebrates. Sites featuring a range of topographic features such as cliffs, banks, hollows and pools of different dimensions and aspects provide a greater diversity of invertebrate habitat than those which are more homogenous or 'neat'. Steep slopes provide natural slippages which keep patches of bare ground open and reduce the need for on-going management. South-facing cliffs and slopes can be of particular value to warmth-loving (thermophilic) invertebrates such as mining bees and tiger beetles. These features should be retained wherever possible, consistent with the requirements of health and safety.

Complexity on a small scale benefits invertebrates. Micro-topography can have an incredible influence on the suitability of a site to support certain invertebrate species – small depressions, low cliffs, small ponds, even puddles can be useful habitats. The topography of a site creates thermal micro-environments due to varying exposure to sun, wind and rain. A varied topography also produces hydrological variation, ranging from dry soils to areas of marsh, seasonal pools, and more permanent water. Retaining or creating a range of micro-habitats on site, with varied environmental conditions, promotes species diversity since many invertebrates have restricted thermal and hydrological requirements. Micro-topographical variation can also promote plant biodiversity on a site.

The process of aggregate extraction produces interesting topographic features, and there may already be small-scale complexity in a site after working has ceased. Where present these features should be retained as far as possible. 'Tidying up' sites to produce smooth profiles or flat land reduces habitat heterogeneity. More uniform sites can be reprofiled to increase topographic diversity by digging hollows, scrapes, and pools, scalloping the edges of water bodies, and piling up material to create humps, banks and cliffs.

Habitat mosaics

Many invertebrates rely upon a range of habitat features to complete their life-cycles. For example, a solitary wasp may require sand cliffs to nest in, but also depend upon scrub or a particular type of grassland to hunt for weevil prey to feed their larvae, and patches of wildflowers (e.g. umbellifers such as cow parsley, hogweed) to feed themselves. Their demands from a single site are therefore high, needing three or four different components within a short distance in which to live, breed and prosper. In the wider countryside these are often difficult to find in close proximity to each other. Quarries therefore provide conditions that would otherwise severely restrict many invertebrate species in the modern countryside.

Habitat mosaics should be incorporated into larger habitat blocks, e.g. patches of bare ground or ponds within heathland or grassland. This may be achieved through retaining or creating a varied landform.

Above: *Bird's-foot trefoil, an early colonising plant, provides nectar and pollen and is the food plant for Dingy Skipper butterfly caterpillars.*

Bare ground & early successional habitats

Important groups/species: ground nesting bees and wasps, bumblebees, robberflies, bee-flies, ground beetles and tiger beetles, spiders, butterflies and moths (UKBAP species: Dingy Skipper, Grizzled Skipper, Small Blue, Grayling, Silver-studded Blue, Chalk Carpet moth).

Exposed soils and bare ground devoid of vegetation are not often considered to be valuable habitats for wildlife. They are features regarded as unsightly and in need of action to establish vegetation as quickly as possible. However, bare ground is an essential habitat feature for a wide diversity of wildlife including many plants, lichens,

Above: *Terraced cliffs in this sand pit provide valuable nesting habitat for scarce bees and wasps.*

Above: *Super-abundant nectar and pollen sources are rare in the wider countryside, but often establish naturally on quarry sites.* Right: *The Dingy Skipper butterfly is a characteristic species of open habitats on quarries and brownfield sites.*

reptiles, birds, and a huge number of invertebrates. Many of the species which require bare ground are unable to survive without it, and a significant proportion of these are rare or scarce.

Vertical, sloping and flat bare ground offers nesting sites for burrowing bees and wasps. Solitary bees provision their nesting burrows with pollen and nectar, whilst the wasps store insect prey, each wasp species collects different insects. The most suitable substrates are sufficiently friable to allow burrowing, but firm enough to prevent burrows collapsing. Bare ground heats up quicker than vegetated ground, providing the warm conditions required by warmth-loving invertebrates. South-facing cliffs and slopes are particularly useful for these species.

Bare areas are favoured hunting grounds for visual predators such as jumping spiders and tiger beetles. Specialist 'pit predators' such as the larvae of tiger beetles also favour bare ground where they wait in burrows to ambush prey.

Bare ground also provides a germination site for colonising plants. Pioneer vegetation is generally dominated by flowering plants such as Common bird's-foot trefoil (*Lotus corniculatus*), Kidney vetch (*Anthyllis vulneraria*), Horseshoe vetch (*Hippocrepis comosa*), Wild carrot (*Daucus carota*) and Common fleabane (*Pulicaria dysenterica*). These plants provide valuable nectar and pollen sources for a variety of insects such as the UKBAP listed Red-shanked carder bee (*Bombus ruderarius*) and Brown-banded carder bee (*Bombus humilis*). Quarries, due to the impoverished soils, may give rise to extensive swathes of Bird's-foot trefoil and other wildflowers, providing a super-abundance of nectar and pollen.

The early colonising plants are also the host to many plant eating (phytophagous) insects, perhaps most conspicuous are butterfly and moth caterpillar foodplants which favour plants growing in stressed conditions (e.g. high temperature, low nutrients, high or low pH). Kidney vetch, the sole foodplant for the Small Blue caterpillar (*Cupido minimus*), is confined to high pH (alkaline) soils as is Horseshoe vetch - the sole foodplant for Chalk-hill Blue (*Lysandra coridon*) and Adonis Blue (*Lysandra bellargus*). Bird's-foot trefoil is the foodplant for a number of species including Dingy Skipper (*Erynnis tages*), Common Blue (*Polyommatus icarus*), Six-belted Clearwing (*Bembecia scopigera*) and Chalk Carpet moth (*Scotopteryx bipunctaria*).

Whereas in other situations bare ground and sparsely vegetated wildflower-rich pioneer communities are short-lived features – they naturally progress into closed grassland followed by scrub – the harsh soil conditions in quarries suppress this change maintaining a longer continuity of early successional habitats. On active sites extraction operations create new bare ground thus restarting the process. These open habitats were once common in the wider countryside; however changes in agriculture and an intensification of land use has led to the loss of these features. It is the capacity of aggregate sites to provide a continuity of such habitats that makes them such important refuges for many invertebrate species that were previously more widespread.

The latest UKBAP review has added bare ground and pioneer habitat mosaics as a Priority Habitat: *Open Habitat Mosaics on Previously Developed Land.*

Heathland

Important groups/species: ground nesting bees and wasps, ground beetles and tiger beetles, butterflies and moths (UKBAP species: Grayling, Silver-studded Blue).

Heathland is a very important invertebrate habitat in the UK, particularly lowland heaths in southern England which are rich in UKBAP species such as the Heath tiger beetle (*Cicindela sylvatica*), Mottled bee-fly (*Thyridanthrax fenestratus*), Purbeck mason wasp (*Pseudepipona herrichii*) and Silver-studded Blue butterfly (*Plebejus argus*).

Aggregate sites featuring an acidic substrate with low nutrient levels can provide the perfect conditions for creating heathland. The development of new heathland is most successful on sites adjacent to existing heathland from which colonisation can take place. Establishment can be speeded up by the spreading of seeds or cuttings from nearby heathland. If seed/cuttings are to be used they should be spread thinly to promote a more open mosaic, alternatively patches can be left unseeded. Some weed control in the early stages may be necessary (e.g. birch, pine, bracken, and rhododendron). Long-term management, e.g. grazing or cutting, is essential.

Many characteristic heathland invertebrates are associated with features such as bare sandy ground rather than the presence of dwarf shrubs; therefore these features should be retained and managed for.

Left: *Heathland restoration can contribute to the conservation of the Heath tiger beetle (Cicindela sylvatica).*

Grassland

Important groups/species: bumblebees, grasshoppers and bush-crickets, butterflies and moths (UKBAP species: Small Blue, Northern Brown Argus (*Aricia artaxerxes*), Chalk Carpet moth).

A wide range of grassland types can be created on restored sites. The choice of target grassland community depends on physical site conditions such as geology and hydrology. As with heathland, restoration of aggregates sites can make a considerable contribution to BAP priorities such as acid and calcareous grassland.

Wildflower-rich grassland mosaics with patches of bare and sparsely vegetated ground support the highest invertebrate biodiversity.

Species-rich grasslands of high biodiversity interest generally develop on soils with a low nutrient content. Therefore the addition of topsoil is discouraged. Natural regeneration is likely to produce grassland which is better suited to the site conditions. The addition of seed of a local provenance may aid the development of a more diverse flora where a site is isolated from established grasslands. On harsh mineral soils management may not be necessary for some years, however eventually some grazing or cutting will be necessary to maintain the sward.

Right: *The Small Blue Butterfly (Cupido minimus) requires good stands of its caterpillar foodplant Kidney vetch.*

Scrub

Important groups/species: bees and wasps, hoverflies, leaf beetles.

Scrub is useful as a limited component of a re-vegetating site, though problematic if it becomes too dominant and eradicates valuable open areas. Many scrub species are important nectar and pollen sources in spring and early summer, serving many types of insect, some specialists on just one scrub species. The foliage of scrub species support many plant-eating (phytophagous) species including caterpillars and leaf beetles. Scrub can also act as a wind break providing shelter on exposed sites.

Management should aim to contain the spread of scrub, maintaining scattered bushes and clumps, rather than continuous blocks.

Right: *The Amber-shanked mining bee (Andrena tibialis) is active in spring – it relies upon bare ground to dig nest burrows and flowering scrub for nectar and pollen.*

Woodland

Woodlands can be valuable habitats for wildlife, including invertebrates. However, their creation should not be a priority in the design of management plans for most aggregates sites. This is due to the long timescales necessary for woodland of value to nature conservation to develop, and the potential for aggregates sites to provide early successional habitats of high biodiversity value such as bare ground mosaics, calcareous grassland and heathland. New woodland should never be planted on land which supports such habitats or where these habitats are likely to develop. Well intentioned tree planting has damaged many aggregates sites of high conservation value.

Where woodland is the ultimate aim for the site, for example where site restoration can link up existing woodland fragments, then natural succession is the most appropriate restoration method. The woodland will take time to develop, but will be of much greater value to nature conservation. It is also easier, cheaper and produces a species mix suited to the soils. It may be necessary to adjust the species mix by removal of undesirable species once regeneration is underway. If trees and shrubs must be planted on site, for example as screening, then stock of local provenance should be used, and the species selected should be appropriate to the region.

Left: *Managing sites for invertebrates can benefit other wildlife – the Slow worm is a recent addition to the UKBAP.*

Wetlands

Where extraction occurs below the water table, or surface water sits on an impervious substrate, wetland features are created. The term 'wetlands' describes a wide range of habitats - each with a different assemblage of invertebrate species. Wetlands on aggregate sites can of course be of great value to other groups, for example internationally important numbers of wintering waterfowl are known to use flooded sand and gravel workings. As well as rare and scarce species, wetlands often support a high biomass (i.e. large numbers of individuals) of invertebrates which in turn are an important food source for birds and bats.

The extraction industry has made a considerable contribution to wetland biodiversity, particularly through gravel and sand extraction in river corridors creating networks of water bodies. There is a significant opportunity to meet UKBAP habitat creation targets for reedbed, floodplain grazing marsh, and ponds.

There are many publications offering guidance on the creation of wetland habitats, such as reedbed, so here we will focus on highlighting some of the habitats and features of high value to wetland invertebrates and briefly discuss habitat creation and management issues.

Right: *The Black-tailed skimmer dragonfly (Orthetrum cancellatum) quickly colonises flooded gravel workings, and has benefited from new habitat created by the industry.*

Some general principles

In the past aggregate extraction techniques operated on a smaller scale than those employed today. Many old sites feature small complex water bodies and are some of the UK's best sites for dragonflies and other aquatic invertebrates. Modern extraction methods generally create large, often deep and sharp-sided water bodies which form when pumping ceases at the end of operations. In such cases some landforming using on-site or imported inert materials to create complexes of wetlands and water bodies can produce biodiversity-rich sites.

Generally speaking smaller, shallow (less than 2 metres deep) water bodies are of most benefit to invertebrate biodiversity. There are few invertebrate species that will benefit from large expanses of deep open water. Most aquatic plants grow best in water less than 1.5m deep - this is because light penetration is good and the water warms up relatively quickly in spring. The two factors of abundant plant growth and warmth create conditions favoured by dragonflies, water beetles, and other aquatic invertebrates. As a result, in larger water bodies invertebrate interest is likely to be concentrated towards and at the edge.

The recurring theme with this best practice guide is that habitat complexity on both large and small scales benefits invertebrates, and this is no different for wetlands. A complex topography enhances wetlands by providing shelter, and a small scale

Picture credits: left - slow worm © Aggregate Industries; right - Illustration of Black-tailed skimmer © Buglife/Richard Lewington mosaic of wet and dry areas. There may already be small-scale complexity in a site after working has ceased, in which case every effort should be made to retain it. If not, then thought could usefully be devoted to thinking how part, at least, of a site could be made more complex, with humps, hollows and banks.

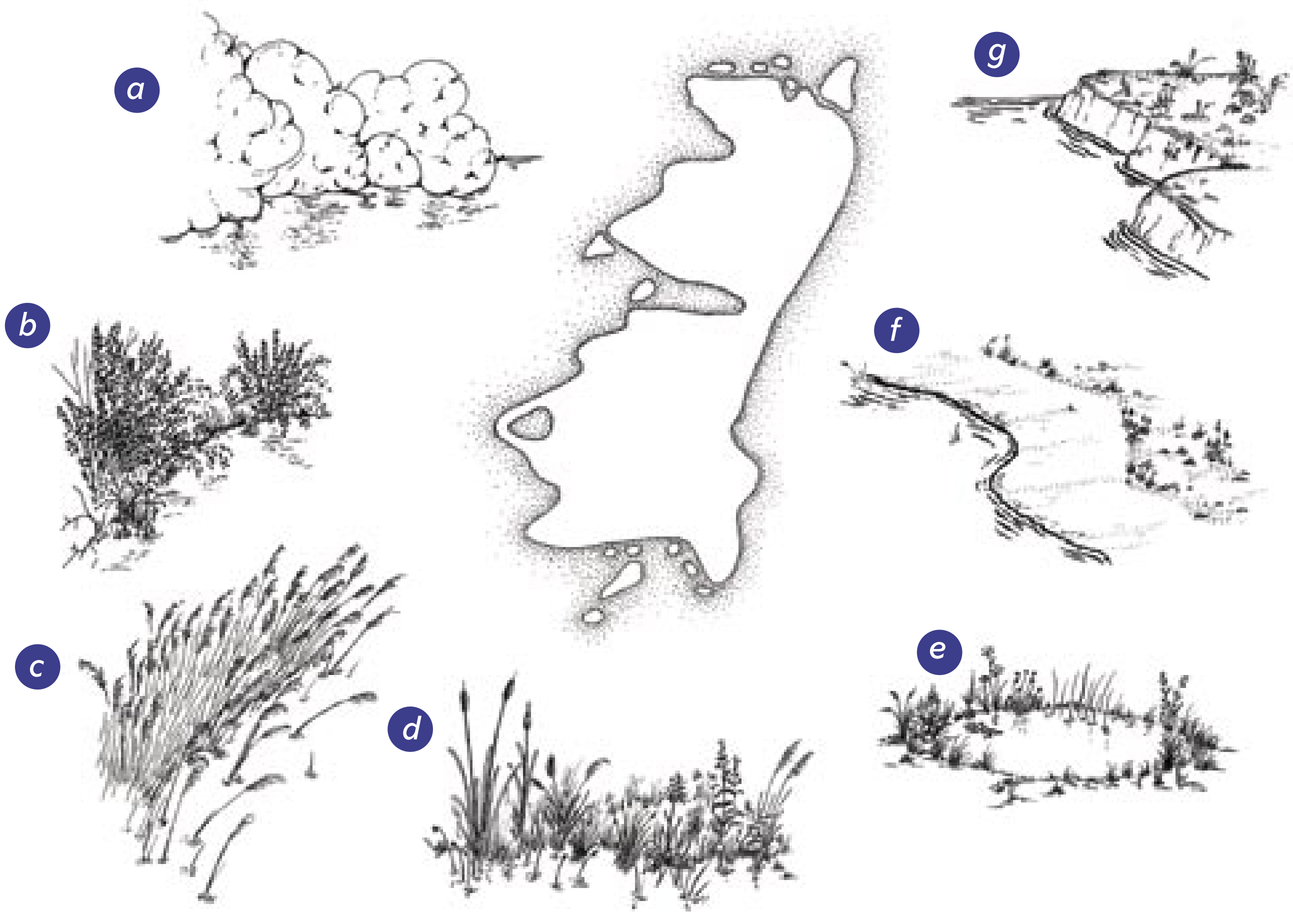
The value of wetland habitats is increased if they form part of a larger wetland complex of wet grassland, swamp, marsh, open water, reedbed or wet woodland. Schemes should include seasonally wet features such as ephemeral ponds as well as permanent water. With large machinery often remaining on site for long periods during restoration works, there are excellent opportunities for creating complex wetlands the minimum of effort. For example a useful pond may be created with a single digger scoop, and a hundred separate digger scoops could make a valuable small-scale pond landscape.

Water levels fall naturally between winter and summer creating a "drawdown zone" at the margins of water bodies; these are utilised by many animals and provide a natural germination area for wetland plants. The mixtures of bare ground and occasional plants here provide an important habitat niche. Some invertebrates will use the drawdown zone during the wet phase; others when it is damp or dry; and some synchronise their life cycle with the seasonal change in water levels. The damp and dry margin is also used by many semi-terrestrial animals including snails, spiders, flies, ground beetles and shore bugs. It is also a favoured feeding ground for many wading birds, and even small mammals.

The urge to plant new water bodies should be resisted. Aquatic plants are accomplished colonisers and will arrive without help. Some of the less common invertebrates and plants of flooded pits are associated with the pioneer stages, and artificially speeding up succession by planting reduces opportunity for these species.

Below: *A complex outline and varied margins will support diverse invertebrate communities.*

a. *Mature willows.*
b. *Scattered scrub.*
c. *Tall swamp with emergent vegetation.*
d. *Shallow marshy margins with varied wetland plants.*
e. *Satellite ponds.*
f. *Gently shelving margins with exposed sediment and sparse vegetation.*
g. *Steep, bare eroding banks.*



Picture credit: Gravel pit illustration © Buglife/Peter Kirby

Large water bodies

On many sites large, deep, steep-sided water bodies are an unavoidable by-product of the extraction process. The depth of the lake bed can be raised by the tipping of over-burden or clean inert fill. Where large amounts of inert material are not available efforts should concentrate on the lake edges and margins. Margins should slope at as shallow a gradient as possible- as a guide a slope of 1:15 or less is useful.

Complex margins of large water bodies can provide a degree of substitution for small ponds: areas in small bays or behind islands provide sheltered conditions; beds of submerged or emergent vegetation in shallows may effectively provide small islands of habitat, or even cut off small marginal areas which function in some measure as ponds in their own right. They cannot fully replace smaller ponds, but can provide useful invertebrate habitat.

Below: *Drawdown zones are important features for both aquatic and terrestrial invertebrates. Southern hawker dragonflies (Aeshna cyanea) often lay their eggs in the damp exposed mud - perhaps to avoid fish predation.*

Reedbed

Large, shallow water bodies created when aggregate deposits are shallow often lend themselves to reedbed creation. A degree of inundation year round is required, as is a relatively stable water level.

At least 700 species of invertebrate are associated with reedbed in the UK; these include a number of rare or scarce species such as the Webb's Wainscot (*Archanara sparganii*) and Rush Wainscot (*Archanara algae*) moths. Common reed (*Phragmites australis*) is the host plant for a range of invertebrates, and Reedmace (*Typha latifolia*) and Yellow iris (*Iris pseudacorus*) both have a number of associated species.

Management should aim to maintain all stages of reedbed succession, from young reed in shallow water to old reed with scrub invasion on almost dry ground over dense litter. Habitat diversity can be promoted further by creating ponds within the reedbed.

Reedbed creation for nature conservation can be combined with other functions, for example producing reed for thatching, biological water purification, and carbon storage. Reedbed can also reduce the amount of open water on site

Picture credit: water body margins © Alice Davies/RSPB

Above: *At least 700 species of invertebrate are associated with reedbed in the UK.*

(sometimes a landscape issue, e.g. where open water is undesirable in a visual sense), and can therefore reduce the risk of bird strike which may be an important consideration in air safe-guarding zones.

Wet woodland/carr

Wet woodland is a rare lowland habitat in the modern landscape and features many species of conservation importance such as the leaf beetle Cryptocephalus decemmaculatus, the Eyed longhorn beetle (*Obera oculata*), the Southern yellow splinter cranefly (*Lipsothrix nervosa*) – all UKBAP species - and the Red-tipped clearwing moth (*Synanthedon formicaeformis*). Willow has a substantial list of rare and scarce invertebrates associated with it. Wet woodland will develop over time on poorly drained or seasonally wet areas; as with other habitats, speed of establishment and the quality of the resulting wet woodland will be improved if similar habitat is present nearby.

Silt lagoons

Silt lagoons are a feature of gravel and sand extraction sites used to contain water on site allowing time for fine material to settle out to allow reuse of water in aggregate processing.

Silt lagoons are ideal early successional wetland habitats for aquatic invertebrates, those with an aquatic stage in their life cycle, and invertebrates that have associations with aquatic plants. If left to natural colonisation silt lagoons will develop the full range of successional habitats from mudflats and reedbed through willow carr and to wet woodland – all stages are of value to invertebrates.

Seepages

Seepages are often associated with cliffs but can also arise from the ground as flushes. These groundwater-derived features create marshy and wet areas in which unique communities of plants and animals thrive, many of which are of conservation interest. The Scarce blue-tailed damselfly (*Ischnura pumilio*) breeds in shallow pools and seepages, favouring those with little vegetation. This damselfly is known from a number of quarry and pit sites where spring lines have been disturbed, and as such has benefited from the extraction industry. Many flies utilise seepages including craneflies and soldierflies such as the Banded general (*Stratiomys potamida*).

Seepages are particularly vulnerable to changes in site management, as they are often inconspicuous and may not be thought of as being of conservation importance. Slight changes in site hydrology can lead to the loss or degradation of these features. Seepage features should be retained in site restoration plans, and can promote biodiversity within active sites where left undisturbed.

Rivers and floodplains

The restoration of lowland sand and gravel quarries adjacent to engineered rivers offers opportunities to reinstate natural features. River braiding can be employed to initiate dynamic river processes, and recreate valuable river channel wildlife habitat such as backwaters, river cliffs and depositional features like sediment bars. Another opportunity is through the reinstatement of flood plain dynamics, which can alleviate flooding as well as provide habitat.

Ponds

Important groups/species: flies (including soldierflies), water beetles, aquatic bugs (heteroptera), snails, dragonflies and damselflies.

Creating new ponds is one of the best ways to benefit wetland wildlife. Ponds are an important habitat for freshwater invertebrates, with about 60% of the UK's larger freshwater invertebrates (e.g. dragonflies, water beetles, water snails) living in them. Pond invertebrates are, in turn, an important food source for amphibians, birds and bats.

Ponds are now a UKBAP Priority Habitat. Creating ponds with a high quality potential contributes to

national and regional targets of the Pond Habitat Action Plan (HAP), and has the potential to contribute to the conservation of rare and scarce invertebrates and other associated wildlife.
There are many opportunities for pond creation on aggregate extraction sites. Ponds are easy and cheap to create as part of the restoration process, during ongoing site management, or on active sites where appropriate. They can be incorporated as features within wetland and terrestrial habitat creation plans and will add considerable biodiversity value.

Pond creation

The aim of pond creation for invertebrates is to make ponds with good water quality, which provide different hydrological regimes with a diverse range of micro-habitats to provide shelter, food, egg laying and emergence sites. Variables include water depth and substrate topography, types of water plant (e.g. marginal, floating-leaved and submerged species), different amounts of shade or shelter, degree of plant cover, substrate type (e.g. gravel, sand or silt). Schemes should aim to create a complex mosaic of pools and wet habitats, rather than a single large pond. The greater the variety of ponds the better, ideally creating permanent, semi-permanent, and seasonal ponds.

Clean water is the most important influencing factor in creating ponds of value to wildlife. Locate new ponds where water pollution from surface run-off is minimised. Avoid linking ponds to rivers, streams and ditches, as these are often polluted by nutrients and silt. At lake sites where over-grazing and trampling by waterfowl (e.g. large flocks of Canada geese) is likely to be a problem, locate ponds away from larger water bodies, where they are less likely to be impacted by birds. Quality is more important than quantity. It is better to have a shallow pond with good water quality which dries out occasionally than a deep water pond with polluted water.

Complexes of smaller ponds can be of greater value than large singular ponds – they provide a wide range of ecological conditions and are able to support a higher biodiversity. Include temporary (ephemeral) ponds - they can support a surprising diversity of invertebrates and are less susceptible to colonisation by fish.

During periods of low water, the exposed mud in the drawdown zone at the edges of ponds is used by both aquatic invertebrate species, including dragonflies and water beetles, and terrestrial species such as flies, snails and ground beetles that live at water margins. Create a wide, shallow drawdown zone, with a convoluted edge and as many bumps and hollows as you can to provide a variety of micro-habitats (*Figure 1*).

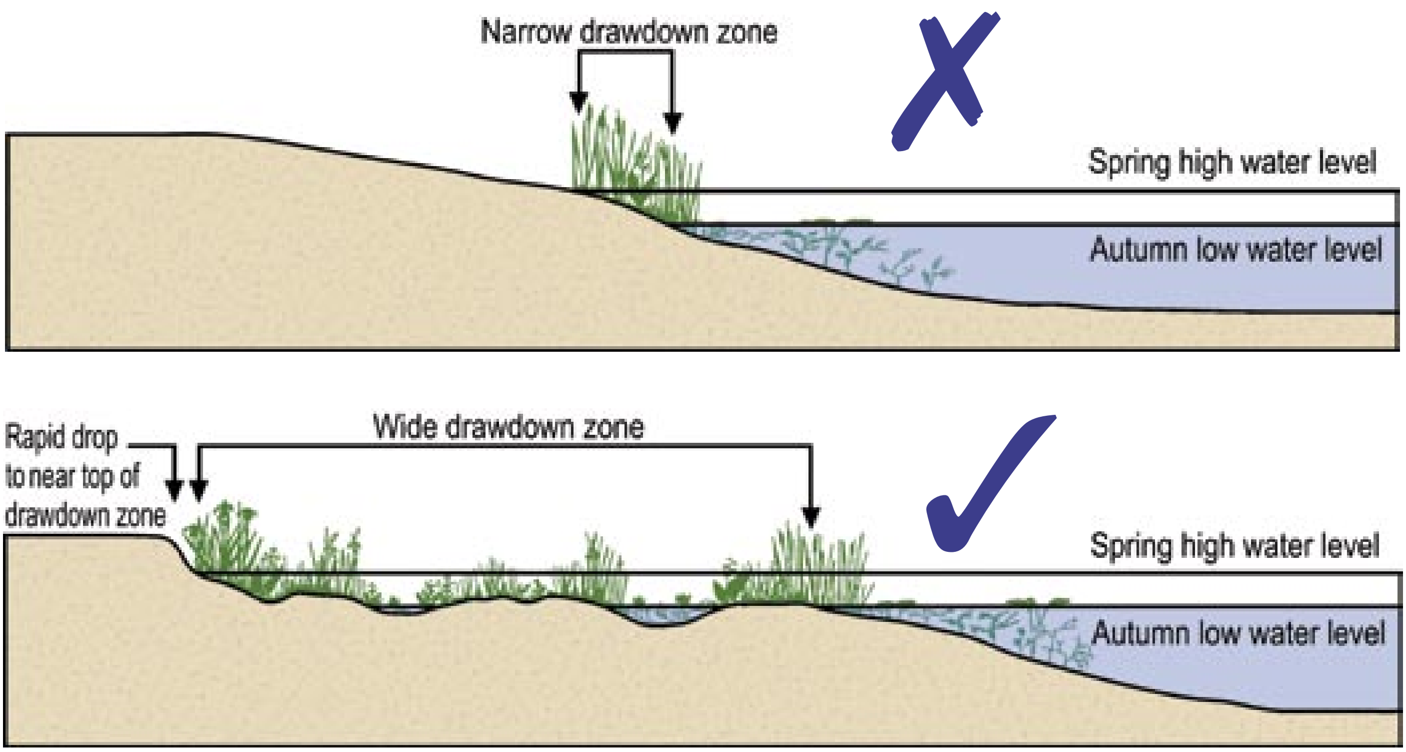


Figure 1. A wide shallow drawdown zone with bumps and hollows will create a variety of micro-habitats for plants and invertebrates.

Picture credit: Figure 1 courtesy of Pond Conservation

Planting up of new ponds is not necessary. Pond plants are very effective colonisers, and if left to nature the resulting pond flora will be more appropriate to the conditions and the locality. The early stages of pond succession are usually short lived but provide an essential habitat for specialist pioneer invertebrates including various species of water beetles, water bugs, and even some dragonflies such as the Black-tailed skimmer. If planting is considered necessary for non-ecological reasons, then locally-sourced native plant species should be used. A little plant management can be useful in the first few years to influence the development of the pond and to ensure that species like Reedmace and Common reed do not become the dominant species. Do not stock ponds with fish as they are major invertebrate predators and can have a detrimental impact on the developing flora. In deep, permanent ponds they are likely to colonise naturally anyway.

Above: *Warm water and abundant plant growth at shallow pond margins create conditions favoured by dragonflies, water beetles and other aquatic invertebrates*

High quality pond creation for invertebrates can be achieved by following the following principles:

- *Good water quality is key.*
- *Complexes of many ponds with a range of sizes and depths are better than single large ones.*
- *Shallow, convoluted margins are better than steep, straight ones.*
- *Planting is not necessary, but some management may be.*
- *No fish!*

Picture credits: top - Pond margin © Dave Smallshire; left - pond illustration © Buglife/Ian Jackson, the Art Agency; Southern hawker © Andrew Whitehouse

LONG-TERM MANAGEMENT

Management techniques

The majority of habitats require some kind of ongoing management to maintain their wildlife interest; grassland and heathland will need grazing or cutting, reedbed will need cutting. For some sites the control of invasive species such as buddleia, rhododendron, bracken or birch will be a main focus. There are many sources of generic management guidance for heathland, grassland and wetlands, so these will not be discussed here. Although it is worth making the point that any management regime should be tailored to the site and should take into account all of the ecological interest present.

The advantage of aggregates sites is that the harsh conditions presented by mineral soils (lack of nutrients, instability, drought and heat-stressed conditions) can suppress or delay natural succession, maintaining open habitats for extended periods. This is one reason why so many old sites are of high ecological interest. However, bare ground will eventually vegetate, open grassland swards will close up, and coarse grasses and scrub will come to dominate. In such cases the process can be reset by re-profiling areas in imitation of the original extraction process, or digging scrapes. Such management should be targeted at areas of low ecological interest and should aim at maintaining a continuity of stages from bare mineral soil to fully vegetated areas. A proportion of scrub and young trees is beneficial, but this should be maintained at less than 15% cover overall and should not be allowed to dominate any one area; scattered bushes are much more important than dense blocks of scrub. Once an area becomes heavily invaded by trees and scrub it is time to re-profile it.

A similar philosophy should be adopted for ponds - the best long-term management being to create new ones rather than clearing or de-silting old ones.

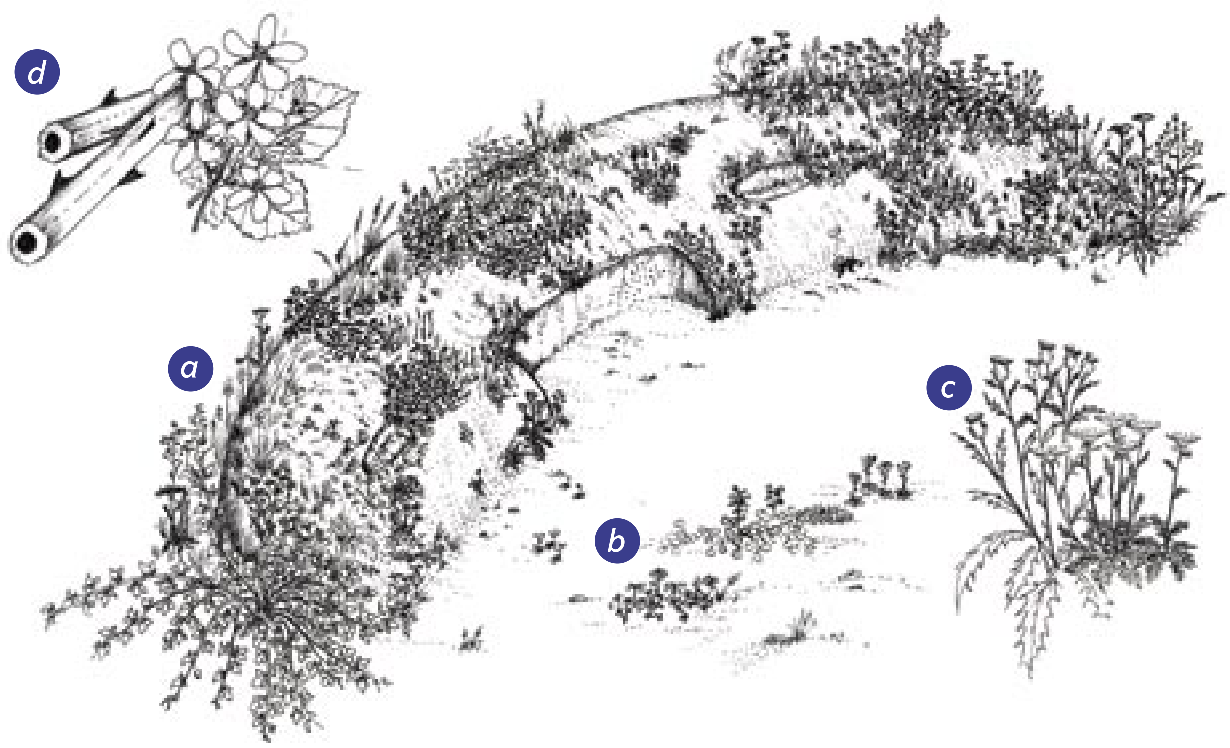
Below: *The construction of bee banks can create new bare ground habitat and add topographic interest to sites. Their effectiveness for invertebrate conservation is largely untested, however they could provide useful habitat for ground nesting bees and wasps and warmth-loving species such as Dingy Skipper and Small Blue butterflies.*

a. *Bare ground and a varied structure provide a wide range of foraging and nesting opportunities.*

b. *Open-structured vegetation in front of the bank provides extra habitat and does not shade the bank.*

c. *Taller flower-rich vegetation nearby provides important foraging areas.*

d. *Bramble and other scrub in the vicinity provides a nectar and foraging resource, broken stems can provide nesting sites for stem nesting species.*



Picture credit: Bee bank illustration © Buglife/Peter Kirby

Resources and sustainability

A common problem encountered with the management of aggregates sites post-extraction is a lack of resources. In order for the management and after-use of a site to be sustainable in the long term, provision should be made for longer term management at the beginning of the restoration planning process. Any necessary funds should be accounted or planned for as part of the whole extraction operation and not seen as something that is an additional cost after the event. Costs saved through adopting a less intensive restoration scheme could be used to set up a fund for long-term management.

For agricultural restoration the statutory requirement to provide five years of after-care is probably sufficient, since after this period the land may be generating income to be sustainable. However, for nature conservation five years after-care is generally inadequate. Many habitats can take 20 years to fully establish and reach the restoration target, some even longer. Anything other than a climax habitat will need managing indefinitely, for example the grazing or cutting of heathland.

Of course, the full costs of indefinite site management cannot be borne by the operator; however, it is best practice to make some assessment or plan of how the site is to be managed in the long-term. Potential sources of funds other than continued financial support for the operator include: agri-environment grants such as Environmental Stewardship, the Aggregates Levy Sustainability Fund, and the Landfill Tax Credits Scheme.

Opportunities for biodiversity within active sites

Left: *Sand martins frequently colonise sand cliffs in active quarries and are accommodated within working operations. The same cliffs are also utilised by mining bees for digging nest burrows – they are behaving in a similar way just on a smaller scale. Encouraging the development of patches of wildflower-rich grassland in the vicinity will provide a nectar and pollen source.*

Working quarries and other extraction sites are often thought of as noisy, dusty and ecologically sterile places; however, despite the disturbance created by the extraction process, much wildlife can survive on working aggregates sites. Some specialist species even thrive and can be dependant on the disturbance created by the operations for their conservation.

Through careful management, quarries can significantly enhance the biodiversity of an area and provide much needed habitats and refuges for wildlife. There are plenty of opportunities to accommodate wildlife within active sites. Many invertebrates readily colonise, especially if areas are left undisturbed for sufficient periods. Invertebrates can benefit from relatively small patches of suitable habitat within sites where these are part of larger networks of habitat patches.

Making space for wildlife need not be high cost or inconvenience normal operations. Awareness of a site's most valuable wildlife features or areas and a flexible approach can enable biodiversity to be integrated within the operation. Colonising plants and animals can provide a solid ecological base for eventual restoration, and can be encouraged with the final scheme in mind. Most sites feature small areas of original habitat which will remain undisturbed, these can act as a refuge for species and a source population for recolonisation.

High quality habitats for invertebrates that can be managed for in active quarries include: temporary and early stage ponds and pools, ditches and

Picture credit: Sand martins © Andrew Whitehouse other drainage features, groundwater seepages, bare ground and sparsely-vegetated wildflower-rich grassland, south-facing cliffs and slopes. On sites where these features have developed effort should be made to retain them somewhere on site throughout its operation. Many invertebrates of early successional or ephemeral habitats are efficient at dispersal and colonisation and may be able to persist on site despite periodic habitat disturbance. As such, some flexibility may be acceptable on the actual location of the features, i.e. as long as there is continuity of suitable habitat somewhere on site populations may continue to exist. Where possible, these features should be retained and incorporated within the eventual restoration scheme.

During most operations a small proportion of the site will always be undisturbed for a time, useful habitat can establish in these areas even if the undisturbed period is temporary. Interim site restoration presents further biodiversity opportunities for areas inactive over longer periods and can be an opportunity for testing out more experimental restoration techniques or studying what habitats and species may colonise the larger site.

Above: *The Scarce blue-tailed damselfly (Ischnura pumilio) can occur on active sites at spring-fed seepages and in small shallow pools. Water-filled vehicle ruts can also provide suitable micro-habitat.*

Above: *Undisturbed drainage ditches can accommodate wildlife within working quarries.*

Integrating invertebrates – combining biodiversity with other restoration end uses

Through careful planning wildlife can be provided for alongside other end-uses such as public amenity, recreation, agriculture and conserving geodiversity. The overall biodiversity value of a site with multiple end-uses will be lower than if all the resources were directed towards a nature conservation end use. Nevertheless, there are plenty of opportunities to create useful habitats and features for invertebrates within schemes. In fact as a group invertebrates are very accommodating, and invertebrate conservation is very compatible with many end uses if managed sensitively. Relatively small areas of suitable habitat within sites can support high invertebrate biodiversity, there are none of the disturbance issues associated with birds, and some disturbance, e.g. path trampling, can be of benefit.

Picture credits: left - illustration Scarce blue-tailed damselfly © Buglife/Richard Lewington; working sand quarry © Roger Key

Many restored sites are used by schools and community groups for educational activities related to the environment, such as bird watching and pond dipping. In areas where access to wildlife is poor they can be an important resource for reconnecting people with the natural world. Access to natural green space can also have positive benefits to physical and mental well-being.

The sowing of native wildflower seed mixes to create flower-rich grassland can provide colour and amenity to sites where public access and recreation is a target end use. Generalist invertebrates such as some of the more common bumblebees and butterflies will take advantage of the habitat and the nectar and pollen it provides, although more specialist species are unlikely to colonise if their more exacting needs are not provided for.

Although large blocks of habitat yield the highest return for biodiversity, some small scale features or relatively small patches of high quality habitat can provide valuable resources for invertebrates. Metapopulations of more mobile species such as the Dingy Skipper butterfly can thrive within networks of relatively small patches of suitable habitat. These networks of habitat patches can be easily incorporated into most end uses, particularly those which do not require the entire site. For example, appropriately managed areas of rough within golf courses or on lakes used for water sports where activities can be contained leaving undisturbed sections. Good site design can focus activities that are less compatible with nature conservation away from sensitive or fragile habitats and species. One example is complexes of water bodies used as fishing lakes; fishing activities can be restricted to one group of ponds, whilst an equal proportion can be dedicated to nature conservation.

Combining public amenity, education and nature conservation can yield benefits for local communities and be a useful tool for demonstrating the industry's commitment to sustainability and nature conservation.

Below: *Managing sites for biodiversity can provide educational resources for local schools and communities.*

Linking Biodiversity and Geodiversity

Many aggregates sites are recognised as being important for their geological interest (geodiversity) as well as their biodiversity, and there are clear links between the conservation of both. Typical management of geological sites involves maintaining natural processes (river and coastal erosion, land slipping), and clearing vegetation to allow access to geological features. Clearing vegetation for access creates bare ground, rock, and open mosaic habitats of value for invertebrates (although ecological advice should be sought when planning clearance works). Geologists often call for the retention of exposed cliffs and slopes; these are also useful invertebrate habitat providing nesting sites for burrowing bees and wasps. Effective communication between geologists and ecologists will ensure that management does not damage either interest, and is of mutual benefit.

Clearing vegetation for geodiversity conservation can also create habitat for ground-nesting bees and wasps such as the Sand-tailed digger wasp (Cerceris arenaria) which digs its nest in bare sandy soils.

Picture credit: top - Looking for bumblebees © Greg Hitchcock; left - Sand-tailed digger wasp (*Cerceris arenaria*) © Andy Phillips

SURVEY AND MONITORING

Invertebrate surveys should be carried out as part of any ecological assessment, in particular at both the initial planning stage and prior to any restoration work. This will allow a better informed assessment of the biodiversity impact of operations and the potential biodiversity gain through site management and restoration. There is a particular need for survey where there are predicted impacts upon habitats of high value to invertebrates such as ponds and early-successional habitats, where UKBAP or other species of conservation concern (Red Data Book, Nationally Scarce) may be affected, or where a site is adjacent to areas of known invertebrate interest.

Undertaking invertebrate surveys and seeking specialist entomological advice should be an integral component of the design of site restoration plans. There is a need to gather information regarding the ecological requirements and conservation significance of the species that (a) have colonised the site, (b) could potentially colonise the site's habitats, (c) could potentially colonise the site if certain habitat creation work is undertaken. This will require knowledge of the species present in the wider local area – the local Wildlife Trust or Local Records Centre may be able to supply information at first hand or tap into National databases.

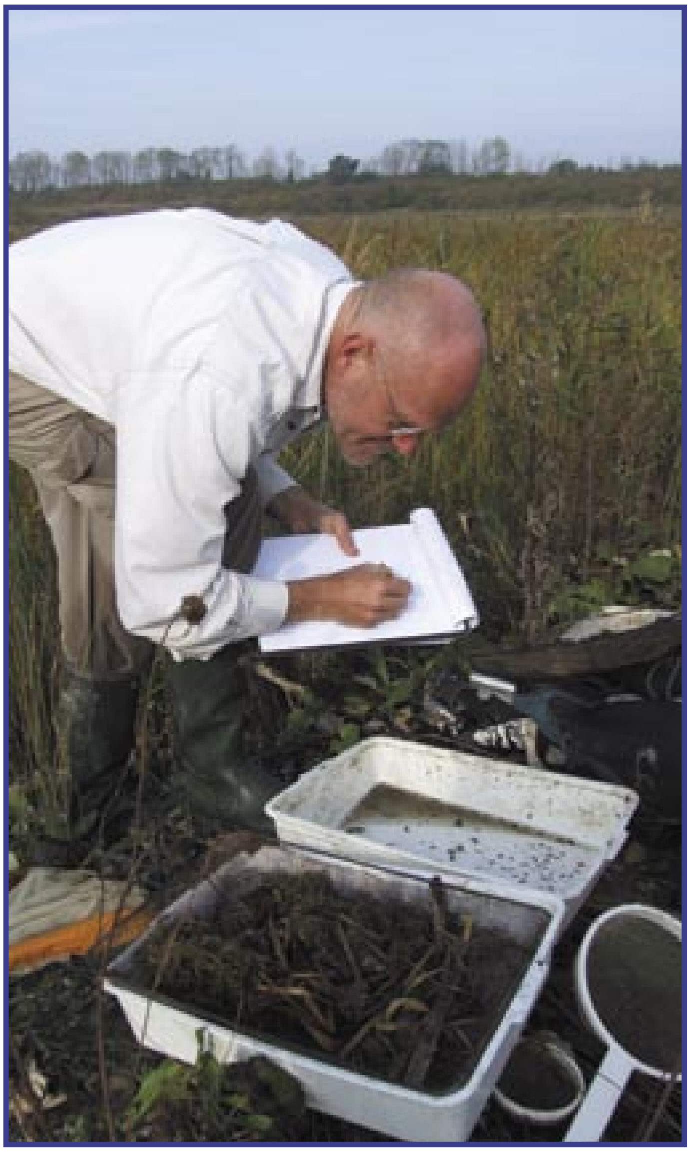
Surveying for invertebrates – nuts and bolts

Employ a specialist: Because of the vast number of species and the range of different invertebrate organisms involved, competent surveys and advice can only be provided by an invertebrate specialist (or entomologist). Entomologists will often only be expert is certain groups of invertebrates, but will usually be able to access other expertise if need be.

Gather as much information as possible: Extensive surveys will reveal more about a site and its invertebrate fauna. 5-10 visits may be necessary to a site in a single year to attain enough information to make well-founded recommendations for a site.

Allow enough time for survey: Many species of invertebrate only appear for a specific short period during the year. To ensure good coverage it is important to organise a survey well in advance of the start of the survey season, which is from March through to late summer or autumn (depending upon groups identified to be surveyed).

Retain the expertise: Keep the entomologist on board throughout the design and implementation of the restoration plan to help provide advice and guidance. After working on the site extensively for a year, they will have a good knowledge of what is required from a scheme to assist the successful creation of new habitats or management of existing ones to promote invertebrates.



Above: *An invertebrate specialist at work.*

Monitoring

Monitoring the success of site management techniques and habitat creation schemes is vital. Monitoring of ongoing habitat creation and post-creation management will flag up any issues with management or where features are not producing good results and require adjusting. It is rare for a habitat creation project to be perfect at the first attempt.

Many habitat creation techniques are experimental, and with each new scheme our knowledge of the subject develops further. Every habitat creation scheme should be viewed as an opportunity to learn and share best practice.

Picture credit: An entomologist at work © Andrew Whitehouse

Conclusions

The aggregates industry can, and does, make a significant positive contribution to nature conservation in the UK.

The extraction process creates habitats of value to rare and scarce invertebrates such as bare ground and sparsely vegetated grassland.

There are many opportunities for making space for invertebrates and other wildlife during the active phase of operations.

Appropriate habitat creation through site restoration can provide vital habitat for the conservation of both common and rare invertebrates.

Site restoration and management for invertebrate conservation is often a lower cost option with maximum benefit for biodiversity.

Recommendations

Invertebrate conservation should be an integral part of any site restoration plan for nature conservation, with equal status to other biodiversity objectives.

The importance of naturally establishing habitats for local, rare and endangered invertebrate populations should be recognised and these features retained or created within restoration schemes.

Restoration schemes should more closely align with Biodiversity Action Plan priorities at both national and local levels.

Restoration schemes should be well monitored both in the short and long term to develop a better understanding of restoration ecology, and results should be communicated to others in the industry and beyond.

Picture credit: Opportunities galore! © Nick Mott

FURTHER INFORMATION & ACKNOWLEDGEMENTS

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Pond Conservation
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Picture credit: illustration - Rugged oil beetle (*Meloe rugosus*) © Buglife/Richard Lewington

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