



# Coastal sand dunes in Wales

## What are sand dunes and why are they important?

Sand dunes are natural coastal landforms and ecosystems located above the high tide mark. Sand dunes form where a beach is big enough to allow the sand to dry out between tides and onshore winds are strong enough to blow the sand inland. Dunes are naturally dynamic systems which are constantly changing in response to changes in rain, wind and sand supply.

Since dunes can only form in locations where environmental conditions are suitable, they cover a relatively small total area in Wales - approximately 8,100 hectares (81 sq. km) or around 0.3% of the land surface.

Sand dunes support many specialised plant and animal species, making them one of the most natural and biodiverse habitats in Wales. They are particularly important for rare plants (including mosses and liverworts), fungi and invertebrates. Dune ecosystems exhibit a great diversity of vegetation types and micro-habitats, from sand sedge-dominated bare sand to luxuriant carpets of orchids in wet areas.

Sand dunes are the most common example of a psammosere (a seral community) where ecological zonation and succession can be easily observed; from bare sand progressing inland through the seral stages to more stable and fixed vegetation communities.

The high wildlife value of the sand dunes has been recognised, and in Wales the majority are designated as Sites of Special Scientific Interest (SSSI) and some are National Nature Reserves (NNR). The larger systems are also classed as Special Areas of Conservation (SAC) indicating their international importance.

As well as being biodiversity hotspots, sand dunes, if managed sustainably, can provide a number of other essential services to people. Dunes provide natural coastal defence and flood protection, as well as water storage. They support populations of bees and other essential pollinators for our food crops and provide beautiful locations for exercise and recreation improving our wellbeing.

### Ecosystem services provided by sand dunes

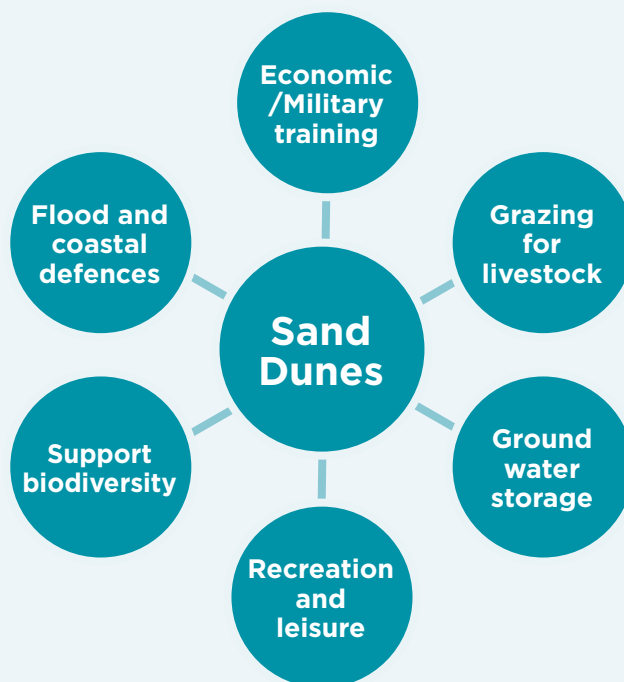


Figure 1



## Sand dune locations in Wales

Examples of the important and significant sand dunes in Wales are shown on the map and in the photographs below.



Newborough Warren



Morfa Dyffryn



Pembrey Burrows



## What is sand?

Sand is naturally occurring finely divided rock and minerals, comprising of particles ranging from 0.06 mm to 2 mm. It is formed as a result of millions of years of weathering and erosion of igneous, sedimentary, and metamorphic rocks. Sand comes in a range of colours and is composed of different materials which is often determined by location. The most common component of sand is silicon dioxide (SiO<sub>2</sub>) usually in the form of quartz, along with many other minerals in smaller quantities. In Wales, the sand includes shell fragments, making it calcium rich, with an alkaline pH.

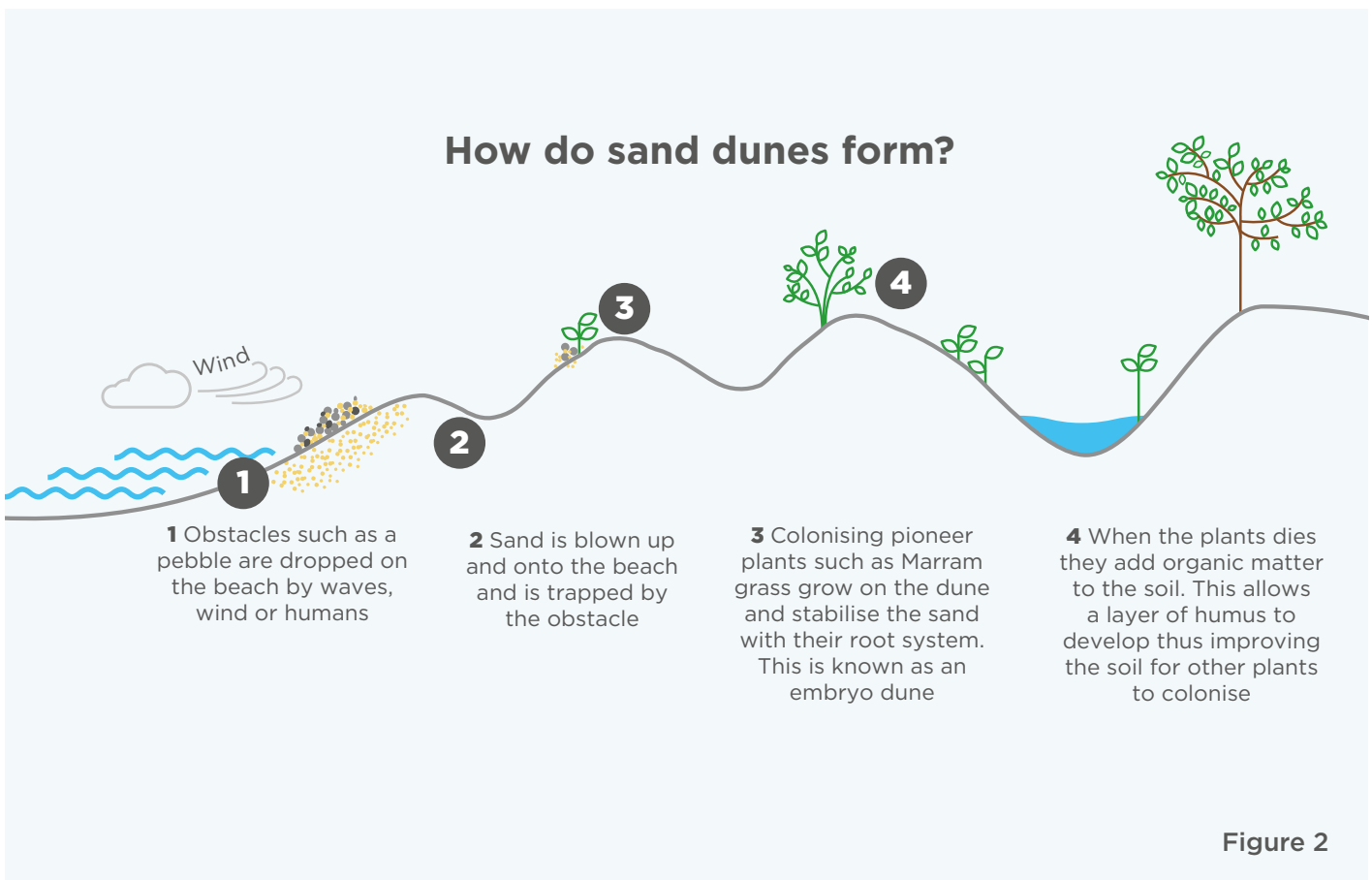
Much of the sand found along the coast of Wales was deposited as ice sheets retreated after the last Ice Age and is now present in offshore banks and along our beaches. However, sand is also created by the ongoing erosion of cliffs, and the breakdown of larger particles (pebbles, rocks, gravel, and shells). Weathering processes such as wind and rain, the freeze/thaw cycle and abrasion by wave action break down these materials into smaller grains.



## How do sand dunes form?

Offshore sand is generally transported to the beach by waves, but can also be transported by tides and storms, all of which stir up sand from the seabed and allow it to be moved towards the coast. If the wave conditions are favourable, sand will be deposited, building up the beach. The process of longshore drift also plays a part in transporting sand from elsewhere along the coastline. Rivers can also bring sand to the coast from inland, and erosion of nearby cliffs and larger particles already in situ, add to the sand supply. Dunes tend to form in places with a wide sandy beach at low tide, as this provides a source of sand to feed the dunes.

1. Obstacles such as wood, pebbles or seaweed are dropped on the beach by waves/wind, usually at the high tide mark (the strand line).
2. Sand is blown up the beach by the wind. This is known as aeolian transport. It can happen in any of three ways: saltation, suspension and surface creep. Once higher up the beach the sand is trapped by the obstacles and the start of the processes of dune formation begins.
3. Colonising pioneer plants such as Marram grass grow in these small hummocks, stabilising the sand with their roots and allowing more sand to collect and build up into ever larger dune ridges. When the plants die they add organic matter to the soil which improves conditions for other plants to colonise, so perpetuating the process of dune development.





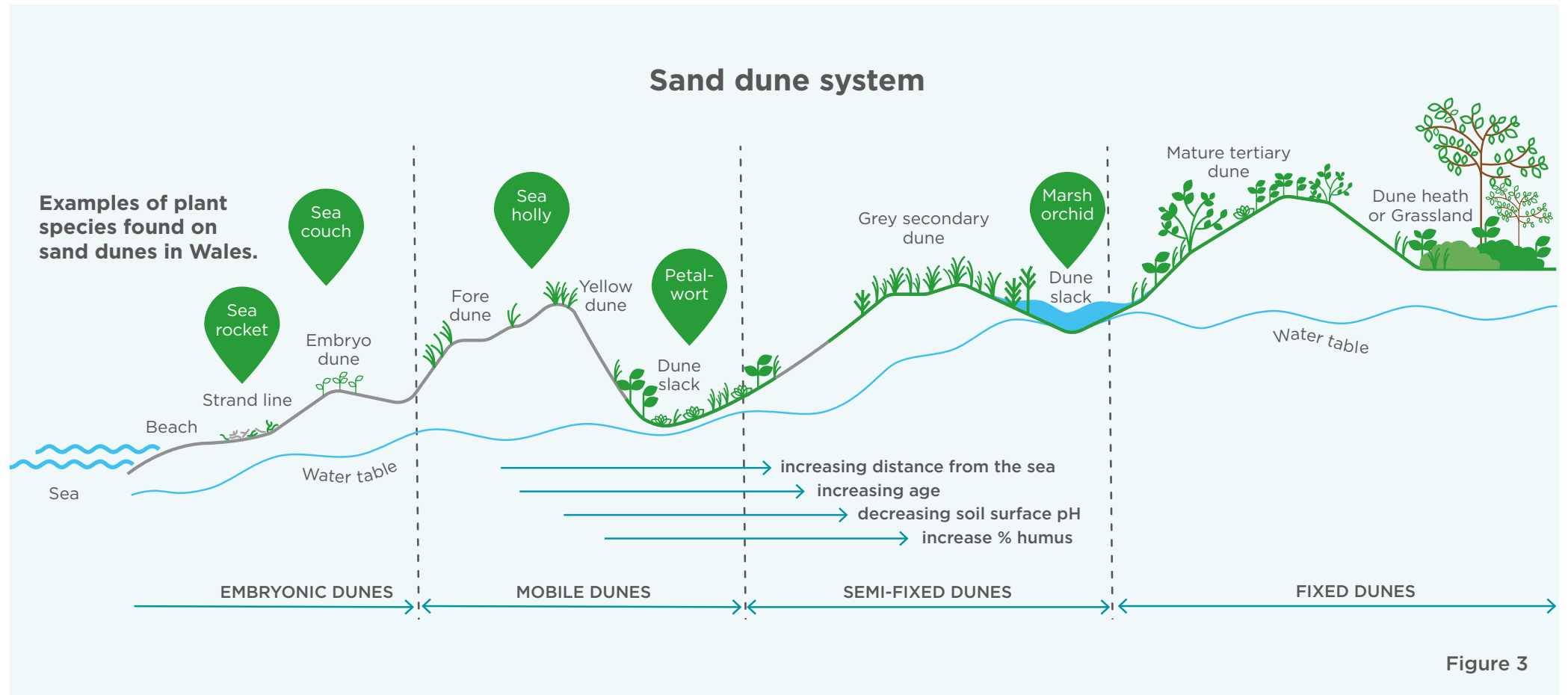
## Natural processes effecting sand dunes

Dunes are constantly changing due to the forces acting on them such as wind, waves, tides and weather conditions. Dune systems can accrete (build up) or erode, or move along the coast or inland depending on environmental conditions.

<p><b>Wind and waves</b></p>	<p>Calm wind conditions lead to constructive waves where the swash (forward movement) is stronger than the backwash, and this allows sand to be deposited on the beach. This sand can then feed the dunes.</p> <p>With strong winds and storms come bigger destructive waves where the backwash is stronger than the swash. These waves can remove sand from the beach and lead to erosion of the embryo and fore dunes. Near vertical cliffs of sand can form at the top of the beach.</p> <p>However, when the tide is out, strong winds can blow sand from the beach up into the dunes, and can also blow dry dune sand further inland and modify the shape of the dunes.</p>
<p><b>Tides</b></p>	<p>At low tide, the beach is at its widest and where the sand dries out it can then be moved by wind action (aeolian transport) which can supply sand to the dunes.</p> <p>At high tide, the beach is mostly under water and sand cannot be transported to the dunes. If strong winds, waves or storm activity occurs when the tide is in, this can wash away some of the dunes. The sand that is washed away may be deposited on the beach or in offshore banks. These banks help to protect the beach from strong waves and enable wider beaches to form. The sand that was washed away, can make its way back on to the beach and into the dunes over time, when the wave conditions are right.</p>
<p><b>Weather</b></p>	<p>If the weather is hot and dry, the volume of fresh water in the dunes reduces, and vegetation grows slowly or dies, leading to more instability and sand movement in the dunes.</p> <p>In wet conditions the sand becomes heavy and compacted reducing sand movement, and limiting the creation of new dunes and the topping up of existing dunes.</p>

## How the sand dune develops

Sand dunes develop over time in a process called succession. Young, embryo dunes form at the beach, with fore dunes and grey dunes further inland and mature dunes furthest from the sea.





## Embryo dunes

Embryo dunes form just above the high tide mark, where driftwood and other debris collects. Pioneer plants begin to colonise, trapping and binding more sand so the first low ridges form.

If conditions allow, the embryo dunes will grow in height and width eventually becoming a fore dune, while a new embryo dune begins to develop in front. The dunes are advancing seaward and new land is forming.

Conditions for plants are extremely challenging and vegetation is generally sparse. Plant species are highly adapted and include Sea rocket, Sea stock, Sea sandwort, Lyme grass and Sand couch grass. Rare invertebrates include the Strandline beetle.



Embryo dune at  
Morfa Bychan



Typical vegetation of  
embryo dunes - Sea rocket

## Fore dune or yellow dunes

Fore dunes are also known as yellow dunes, because of their light yellow colour. Fore dunes, along with embryo dunes, are called mobile dunes as the sand is quite loose and can be blown, and the shape of the dune changed. Many of the dunes in Wales have developed a parabolic or U-shaped formation. Fore dunes can reach heights of up to 20 metres or more in some cases. They are more vegetated than embryo dunes and protect the dunes behind them, but still have plenty of bare sand. The dune crests (tops) are well above the water table, which is often several meters down. As the sand is loose, it allows rainwater to drain quickly through, so plants of the yellow dunes need to be able to cope with extreme drought, as well as the constantly moving sand which can bury them or expose their roots.

Marram grass is the dominant species, but Sea spurge, Sea holly, Sea bindweed and Saltwort are also typical. The rare and protected Sand lizard can be found in the fore dunes.



Fore dune at  
Morfa Harlech



Typical vegetation of  
fore dunes - Sea holly





## Secondary or grey dunes

Once fore dunes, these older dunes are usually the largest within the dune system and can reach heights of over 20 metres, but there may also be extensive lower, undulating dunes or sand plains present. As you move away from the beach, more plants can survive, and a layer of dark-coloured humus (organic soil) develops. Grey dunes are named for their characteristic grey colour which is a result of the ground cover of lichen combined with a topsoil layer of humus. The dunes here are much more stable and there is less bare, mobile sand. They are more able to hold water so you will find shrubs starting to colonise.

Typical species in the grey dunes include Pyramidal orchid, Dune pansy, Wild thyme, Bird's-foot trefoil, Common centaury, and Carline thistle.



Grey dunes at  
Whiteford Burrows



Typical vegetation of grey  
dunes - Common centaury

## Blowouts

Blowouts are formed by wind erosion, particularly during storms. As the wind swirls around, the sand is eroded into a bowl-shape or deep hollow that may reach down to the water table.

They are more common in the fore dunes but can also occur in the grey dunes if plant roots become damaged by trampling or animal grazing and can no longer bind the sand together.



Dune Blowouts at  
Newborough Warren



## Dune slacks

Dune slacks are low-lying, level hollows between the dunes. Most slacks are created when a new ridge forms in front of a low-lying area and others form as a result of a blowout (where sand is scoured away). The wet slacks between dunes are usually flooded in winter and damp underfoot in summer. The damp conditions and higher organic/nutrient content of the soil encourages a very high variety of wetland plants, including Marsh orchids, Helleborines, and Marsh pennywort. Plants that can tolerate being submerged in water during the winter thrive here.

In spring, dune slacks often support breeding amphibians such as Great crested newts, frogs and toads, and on sunny days are alive with insects, such as damselflies or butterflies.



Dune slack at Tywyn Aberffraw in winter



Typical vegetation of dune slacks - Marsh Orchid

## Mature dunes

Mature dunes are also known as hind dunes or tertiary dunes and are the oldest dunes in the system and furthest away from the beach. As the physical conditions become less extreme and organic matter builds up in the soil, increasing nutrient availability and moisture retention, less specialised, more vigorous, common plants can survive.

If given time and space from grazing animals, tall scrub and even woodland will establish as the climax vegetation. Climax vegetation is that found in the final stage of biotic succession in an area under particular environmental conditions. However, if there is a large percentage of grazing livestock or rabbits present, grassland is likely to be the climax vegetation.



Mature dune at Kenfig Burrows





## Dune heath

A dune heath is a rare habitat in Wales; usually found further inland in older dunes where rainwater has leached the calcium content out of the sand, rendering it more acidic.

They are characterised by plants of acidic conditions such as heathers and lichen and species such as Sheep sorrel.



Dune heath at Cymeran



Sheep sorrel at Tywyn Aberffraw

## Surviving in the dunes

Dunes, especially the embryo and yellow dunes, are very challenging environments for plants. The high pH, salinity (amount of salt), strong winds, moving sand and drought means only a relatively limited number of robust pioneer plants, with special adaptations can survive.

Although dunes form above the normal reach of waves, plants are subjected to salt spray and splashes of sea water. During storm surges, the embryo dunes may even get submerged. Therefore, species need to be halophytic (salt tolerant).

Dune pioneer plants deal with high winds and drought by developing tough outer layers which may be waxy or hairy, rolled leaves and long roots, as well as a means of storing moisture.

Dunes are generally very low nutrient environments, so plants are often small with low growth rates. In dune slacks, plants must cope with seasonal flooding.

More competitive, common species cannot survive in the harsh conditions of the dunes, and therefore, healthy dunes are dominated by rare, specialised species leading to the high biodiversity.

## Marram grass

Marram grass is the dominant species in the fore dunes and is supremely adapted to the harsh environment, making it the single most important species in the formation and stabilisation of sand dunes. A halophyte plant, with tough, rolled leaves, Marram copes well with sand deluge (burial) and as the dune grows, Marram can convert buried leaves into roots! Marram roots can reach to depths of several metres and serve to trap yet more sand. As the roots are so long, Marram can continue to extract water even after a long period of drought.





## Humans and sand dunes

People have been affecting dunes for many hundreds of years and human use and management has changed significantly over time.

Although dunes may appear as natural wilderness, they have in fact been farmed and managed by local people for centuries. Grazing of livestock was traditional and rabbits were managed in their thousands for meat and fur, hence the term 'warren' being a common place name.

Newborough Warren is one of the few dunes in Britain where Marram grass was used commercially to make mats, ropes, and baskets. The practice started in the 16th Century and eventually became a thriving domestic industry, until the Enclosure Act of 1815 prevented free access to the dunes.

During the WWII many dunes were used as military training areas, including firing or tank ranges. Remains of pillboxes, railways, and airfield decoy strips can still be found today.



Cwningar Farm at Newborough prior to the establishment of the conifer plantation in 1947.



Tanks at Morfa Harlech

During the 20th Century many sand dunes were lost to residential development, industry and intensive farming. Forestry was also a common land use on dunes, with pine plantations being established for timber and to help stabilise shifting sands. Hard sea defences have also been built which restrict the natural movement of sand along the coastline, and can affect sand supply to the dunes.

Over time people gradually began to recognise the importance of sand dunes as part of Wales' natural heritage and began seeking legal protection. Newborough Warren was declared a National Nature Reserve in 1955 with several others following. All the major dunes systems are now designated as Sites of Special Scientific Interest and Special Areas of Conservation, although many small dunes still do not have any special protection.

In many cases, voluntary sector organisations, local authorities, or government agencies such as Natural Resources Wales, have taken responsibility for managing sand dunes. As well as prioritising biodiversity conservation, managers often look to gain multiple benefits for recreation, health and well-being, open access, and natural protection against flooding and coastal erosion. Not all dunes are open to the public though, as some are privately owned, and in some locations the Ministry of Defence still uses them as locations for military testing and training.

## Current human pressures and threats to Welsh sand dunes

Whilst Welsh sand dunes are still biodiversity hotspots, populations of many rare and specialist species are decreasing and the condition of the habitats are often declining. Most of the dunes are now considered to be in 'unfavourable condition' for wildlife. The reason for this is a range of pressures and threats, which are shown below:

Action	Impact
<b>Lack of sustainable livestock grazing</b>	Grazing by rabbits and livestock such as cattle, ponies and sheep greatly benefits dune systems. Sensitive grazing keeps vegetation low and reduces the amount of fast-growing competitive species so a greater range of species can thrive. Grazing animals also break up the turf and create patches of bare sand. Grazed dunes can support up to 30 plant species per square metre, but in the absence of grazing this may drop to 10 or less. However, many sand dunes are under-grazed as they do not always fit well into modern livestock systems and can be uneconomic or impractical for farmers to graze.
<b>Air pollution</b>	Sand dunes are nutrient poor habitats, and the rarer, specialist dune plants are adapted to these conditions. Air pollution increases the levels of nitrogen as well as ammonia and sulphur dioxide deposited into the ground, enriching the soil, and favouring the growth of a less diverse range of coarse, more competitive species.
<b>Declining rabbit population</b>	On dunes, rabbits are keystone species and 'habitat engineers'. Their grazing creates short lawns ideal for low-growing plants and their burrowing and scraping activities produces bare sand for invertebrates. However, rabbit numbers have decreased significantly in recent decades due to myxomatosis and other diseases.
<b>Invasive alien species</b>	In the past, invasive species not native to Wales, such as Sea buckthorn were planted deliberately to stabilise the dunes. Alien species also arrived from dumped garden waste or on high tides. Once established, such species can spread to smother large areas of dune, destroying natural habitats, and making them impassable to people and livestock.
<b>Afforestation</b>	Conifers were commonly planted on sand dunes in the 20th Century to help stabilise them and as a crop on land which had little alternative economic value. The trees destroy the native vegetation beneath by shading, altering the pH and adding nutrients to the soil. Conifers also take up a great deal of water throughout the year, reducing the amount of groundwater available and drying out nearby dune slacks.
<b>Intensive farming practices</b>	Intensive farming surrounding dune systems may introduce fertilisers and chemicals from run-off and leaching. As sand dune habitats are very nutrient poor, even small amounts can change the plant species composition. The draining of farmland to increase productivity can also impact nearby dunes by reducing groundwater levels and water availability in biodiverse dune slacks.



Action	Impact
<b>Disturbance by visitors</b>	Excessive numbers of visitors and unrestricted activities such as motorbike scrambling, fly camping, or large-scale events can cause disturbance to breeding wildlife and damage to localised populations of rare species. Very high levels of localised trampling can destroy the vegetation and lead to damage to paths and swamping of roads by windblown sand. However, on larger dune systems trampling is generally positive as it helps maintain open sand.
<b>Litter and fly-tipping</b>	Litter can be washed up from the sea, left by visitors or illegally dumped as fly-tipped waste. Litter and waste can smother native vegetation, choke livestock and harm wildlife. It also impacts on the attractiveness of the landscape and spoils the visitor experience, as well as being a potential human health hazard. Animal fouling (e.g. horses and dogs) causes nutrient enrichment, along with barbeques, due to charcoal being left behind. They can also cause fires.
<b>Infrastructure development</b>	Where developments such as houses, caravan parks, golf courses, industry, roads and railways have been built behind beaches and dune systems, 'coastal squeeze' can occur. This is where the dunes get squeezed into a narrow strip between a retreating coastline and the development, leaving no space for the dune to naturally migrate inland. This increases the sand dunes' vulnerability to storms and erosion.
<b>Construction of coastal defences</b>	Man-made, hard engineered coastal defences are constructed to reduce the risk of flooding and/or control erosion locally. The downside of hard defences is that they can reduce the amount of sediment being transported along the shoreline, adversely affecting sand dune systems that rely on a steady flow of available sediment to accrete (grow) and vegetate during calm weather.
<b>River and marine dredging of river and sea channels</b>	Deep channels are dredged in coastal seabed or rivers to allow the passage of large ships. Sand is also extracted from offshore sand banks for industrial or construction purposes. This reduces the amount of sand and sediment in the coastal system, available to feed nearby sand dunes.

### Will climate change impact upon sand dune systems?

Sand dunes are dynamic systems, continually accreting and eroding, so they respond quickly to changes in environmental conditions caused by climate change. Warmer winters and wetter summers are increasing the growth of coarse vegetation on the dunes, while prolonged periods of drought will adversely affect the wetland habitats. The increasing severity of winter storms may have benefits by improving mobility of the dunes, but they can also cause erosion of frontal dunes and coastal flooding.

Due to their naturally dynamic nature, dunes may be able to cope with changes like sea level rise and increasing storminess without being destroyed, by migrating further inland or changing position on the coastline. As most specialist dune species are pioneer colonists, they are particularly well adapted to movement within the habitat. However, successful adaptation relies on there being viable populations present on site, and habitat connectivity between sand dunes, otherwise significant areas will be lost in the long term. In the meantime, it is probably safe to say that a well-managed, biodiverse dune system will be the most resilient to climate change.





## How have dunes changed?

There is one major change over the last 80 years or so which has altered the character of Welsh sand dunes completely.

In the mid-20th Century, up to 80% of the Welsh dunes were covered with bare, mobile sand. Over the subsequent decades the dunes have become vegetated with fixed dune grassland and in places have become overgrown with dense, coarse grasses and scrub.

To some extent the dunes would have vegetated naturally due to the process of ecological succession, but human activities have caused pressures (see above) which have accelerated the process.

As a consequence, the dunes have become over-stabilised and nearly 90% of open sand has disappeared. This has resulted in the loss of bare sand habitats and pioneer conditions resulting in rare wildlife suffering and in some cases, disappearing. Some plant, fungi, and invertebrate species such as Fen orchid and the Crucifix ground beetle, may be facing extinction.

An ideal sand dune system at its most biodiverse will have 30-40% pioneer habitats, including 10-15% bare sand.



**Newborough Warren**  
1950



**Newborough Warren**  
2010

## Conservation management of sand dunes - what has changed?

For decades, dunes were seen as very fragile environments and dune management focused on the stabilisation of sand dunes in the belief that this would help protect them. Practically, this involved planting Marram grass and trees, fencing to trap sand, and avoiding trampling by keeping the public out. However, such measures have only encouraged dense vegetation growth and the loss of species richness on the dunes.

The approach has now changed as ecologists have carried out research and learnt more. Dunes are dynamic, mobile ecosystems, where sand actively moves through the landscape, creating areas of bare sand which are subsequently colonised by a wide range of specialist species. There has been recognition that in order for dunes to be healthy, self-sustaining, and biodiverse they must be dynamic and management is now aimed at supporting these natural processes and encouraging mobility in the dunes.

Some management techniques to encourage dune dynamism can appear initially to be quite drastic and may look like they will increase flooding or reduce biodiversity. However, this is not the case; with clear and considered communication with local communities and visitors, the messages regarding dune dynamism and its importance for biodiversity and dune sustainability will help to increase awareness and understanding.

However, occasionally dune stabilisation may still be relevant in locations where there is only a narrow strip of dune present and there is excessive disturbance or a development close behind, or in locations where sand blowing on to roads and footpaths is a particular problem.





## Practical management techniques - what is being done to restore Welsh sand dunes?

Today management is aimed at restoring a diverse range of early successional stage habitats, and re-creating areas of bare sand, allowing the natural processes driven by wind-blown sand to take place. Here is a selection of strategies being used along the Welsh coastline.

The what	The why and the how
<b>Re-profiling dunes</b>	By creating notches in the foredunes or new blow outs, to encourage sand movement.
<b>Stripping turf from dunes</b>	To create bare sand and early successional-stage habitats, which can be colonised by specialist dune species.
<b>Lowering the surface of dried-out dune slacks (hollows)</b>	To re-create standing water in winter and damp habitat in summer to encourage biodiversity.
<b>Promoting sustainable grazing by livestock</b>	To create a variety of micro-habitats including short grassland and patches of bare ground. Grazing stops coarse vegetation dominating the dunes and results in a species-rich community.
<b>Mowing</b>	To maintain a short grassland sward which favours low-growing, dune-specialist plant species and prevents coarse vegetation from dominating.
<b>Supporting rabbit populations</b>	Rabbits are ideal grazers and habitat engineers for grey dunes as they create a patchwork of closely cropped dune grassland and bare areas, which promotes species diversity.
<b>Removing invasive alien species</b>	To remove species which, if unmanaged will spread, smothering and over-stabilising large areas of dune.
<b>Clearing native scrub</b>	To remove shrubs and bramble which will out-compete smaller specialist species, lower the water table in dune slacks and over-stabilise the dunes.



Turf stripping  
Pembrey Burrows



Large scale scrub clearance at  
Kenfig using tree shears



Cattle at Tywyn  
Aberffraw



## Glossary

The glossary contains a definition of the key coastal processes and sand dune processes found in these resources.

## Additional Reading

Please find below links to some that you may find useful:

Natural Resources Wales is not responsible for the content, standard or reliability of the websites or resources linked from this information note.

Listing should not be taken as an endorsement of any kind. We cannot guarantee that these links will work all the time and we have no control over the availability of linked pages.

**Natural Resources Wales/Sands of LIFE**

**Sand dune management at Kenfig dunes**

**Dynamic Dunescapes - learning resources**

**Dynamic Dunes**

**Depositional coastlines - GCSE level**

**Formation of sand dunes**

**Sand dune ecosystems GCSE**

**All types of Sand dunes**

**Royal Geographical Society - Geography resources for teachers A-level fieldwork techniques**

**Sand Minerals - Sand atlas**

## Looking for more learning resources, information and data?

Please contact: [education@naturalresourceswales.gov.uk](mailto:education@naturalresourceswales.gov.uk) or go to <https://naturalresources.wales/learning>

Alternative format; large print or another language, please contact:  
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