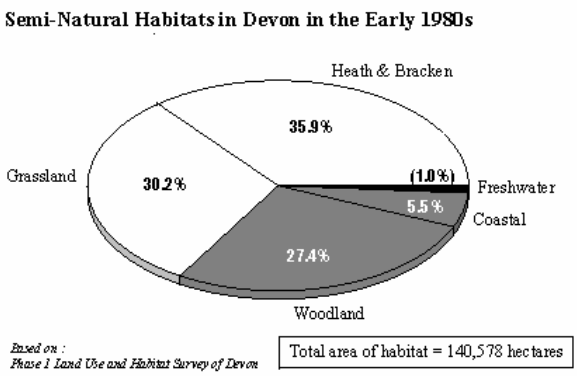
Section D: A review of Devon's wildlife and geological heritage

1. The major habitats in Devon

1.1 Land use and habitats in Devon

Devon is widely acknowledged as being a county rich in wildlife. This is particularly reflected in the diversity and extent of its wildlife habitats which are inextricably linked to the landscape character and scenic beauty of County. A comprehensive and systematic assessment of land use and wildlife habitats undertaken through the Devon Phase 1 Survey between 1983 and 1985 showed that semi-natural vegetation communities covered approximately 20% of the land surface area, although this overall figure hides the significant variation in conditions found around the County from 6.1% cover of semi-natural habitats within Exeter to 61% within Dartmoor National Park.

Shown here is a simple breakdown of the major categories of land-based and coastal habitat in Devon. A more recent and more detailed audit carried out in 1998 of the extent of the principal habitat types found in the County is given in Table 1.



There is currently no corresponding analysis for the composition of marine habitats in the coastal waters around Devon although the available information does suggest that approximately 20% of the sub-tidal environment is dominated by rocky substrates with the remaining 80% comprising sand, mud and gravels.

Appendix iv provides a summary of all those sites in Devon which have some form of designation in recognition of their nature conservation importance.

Table 1 - The approximate extent of the main terrestrial wildlife habitats in Devon (1998)

BROAD HABITAT CATEGORY	SPECIFIC HABITAT TYPE	APPROX. AREA (in hectares)	% LAND COVER
Woodland (1 & 2)	All Woodland	53,813	8.0
	Ancient Woodland	14,922	2.2
	Ancient Semi-Natural Woodland	8,791	1.3
	Parkland	1,753	0.3
	Dense Scrub	3,619	0.5
Grassland (2, 3, 4, 5 & 6)	Chalk and Limestone Grassland	240	0.04
	Neutral Pastures and Meadows	2,000	0.30
	Rhôs Pasture and Marshy Grassland	5,140	0.76
	Coastal Grassland (including mosaics of grassland, scrub and bracken)	3,300	0.49
	Upland and Acidic Grassland (includes grass moorland and associated bracken/scrub)	26,400	3.92
Heathland (2,3,4 & 5)	Heather Moorland	15,650	2.32
	Upland Mire/Blanket Bog	13,800	2.05
	Lowland Heathland	2,850	0.42
Freshwater Systems (2 & 3)	Rivers, Streams & Other Watercourses	c.13,400 km	
	Watered Canal	c.30 km	
	Reedbed (Freshwater) [Only sites > 0.5 ha]	58	
	Reedbed (Brackish) [Only sites >0.5 ha]	34	
Coastal Habitats (2)	Intertidal Shore	4,950	0.74
	Saltmarsh	350	0.05
	Dunes	1,200	0.18
	Cliff and Scree	1,200	0.18

Sources:
The above are estimates based on a wide range of published and unpublished information sources, prominent amongst which are:

1. Devon Inventory of Ancient Woodland.
2. Phase 1 Land Use and Habitat Survey of Devon.
3. Devon Biodiversity Record Centre information based on District-wide Wildlife Surveys.
4. Silsoe College figures on Landscape Change in the National Parks of England and Wales.
5. Dartmoor National Park figures from survey of Duchy Newtakes.
6. Somerset Trust for Nature Conservation Report on Grasslands in Exmoor National Park.

1.2 Woodlands and scrub

Broadleaved woodland is the habitat type which most closely corresponds to the natural vegetation cover that would be expected to be found over a large part of the County. However, the action of man over millennia not only accounts for the current extent and location of woodlands within the County, but has also profoundly influenced the species composition and structure of these woodland communities. Although small tree groups and copses are relatively widespread over the County as a whole, the larger blocks of broadleaved woodland are heavily concentrated within major river valleys where the steep slopes and thin soils are poorly suited to agriculture. Relatively large stands of amenity woodland have been planted within the last few hundred years on the bigger estates across the County and extensive areas of coniferous plantation have been established throughout this Century in areas with poor soils including Dartmoor, on former heathland on the Haldon Ridge and Blackdown Hills and across the 'Culm' of mid and north-west Devon.

Sites which have been continuously wooded since Medieval times - nominally taken to be the year 1600 - are referred to as 'ancient woodland' and are generally regarded as being the most important for nature conservation. Many of these are believed to be surviving fragments of the primeval forests. The importance of these woodlands is based on their long ecological continuity and lack of disturbance to their soils. Woodlands which occupy sites that have not been continuously wooded, and have either been planted or have grown up on open field sites are referred to as 'secondary woodland'. In both categories of woodland, semi-natural communities (which comprise stands of trees which do not obviously originate from planting, with the distribution of species generally reflecting natural variations in site and soil) are particularly important for wildlife and often support a large and characteristic assemblage of associated flora and fauna.

Many of the ancient semi-natural woodlands found within the County, particularly those on the poor soils and higher ground associated with Dartmoor and Exmoor, have a character similar to that of oak woods in other parts of the western Britain and are referred to as 'Western Oak Woods'. These hold an important and distinctive assemblage of breeding birds, including Pied Flycatcher, Redstart and Wood Warbler, and the mild maritime climate and relatively unpolluted atmosphere results in the survival of rich moss, liverwort and lichen communities. Calcareous soils derived from limestones in South Devon give rise to quite a different woodland character, with ash and maple (and occasionally small-leaved lime) prominent within the tree canopy and a far richer

ground flora -including extensive stands of bluebells - and range of shrubs than the more widespread acid oak woodlands. Wet woodland communities, including alder and willow carr, are scattered in small fragments across the County, these particularly associated with flushes, streams and rivers and other waterlogged situations. Plantation sites - even those dominated by non-native conifers - are sometimes important for wildlife and can support notable species such as the breeding raptors and nightjars of Haldon Forest.

A further habitat in which trees are a prominent feature is parkland, although the extent and character of the tree cover is dependent upon the origin and subsequent management of the site. Many parkland sites in Devon, particularly medieval deer parks, are of European significance for their lichens and invertebrates.

There are also extensive areas of scrub habitat within the County which are normally associated with other areas of semi-natural habitat such as grasslands and heathlands. Although scrub can contribute very significantly to the conservation value of wildlife sites, particularly for its associated bird and invertebrate communities, very large and homogenous stands of scrub are often of lesser importance than the open habitats upon which they encroach in the absence of appropriate management.

1.3 Grasslands

Grasslands cover the vast majority of the Devon countryside and accounts for the green and pastoral character of the County. However, the attractive appearance of much of the farmed landscape, with green fields crossed by a dense network of hedgerows, punctuated by pockets of scrub and woodland, hides the fact that grassland is one of the most altered and impoverished of all habitat types. The huge majority of all grassland within the County is heavily influenced by modern agricultural methods, with many fields (grass leys) managed within a cycle of cultivation and re-seeding at regular intervals. Even permanent pasture has its character grossly altered through the application of inorganic fertilisers which quickly lead to the dominance of just a few aggressive and productive species at the expense of the native and diverse flora.

The grasslands that retain the greatest wildlife interest are those which have escaped agricultural 'improvement', often due to the fact that they are found on the most difficult and unproductive farmland. As a result, there is a close relationship between the

occurrence of 'unimproved grassland' and steep slopes, poorly drained and infertile soils. These grasslands generally support a diverse flora and, as a result, a rich associated community of insect life and a wide range (and high density) of small mammals and birds which prey upon these. For example, recent research has indicated that unimproved grassland is an extremely important habitat requirement for the rare Cirl Bunting which relies on the high density of insect life, particularly grasshoppers, to make up a major element of its diet for part of the year.

The precise composition of these grasslands reflects the character of the soils upon which they are found, particularly their lime-content and degree of drainage, thus giving rise to specific patterns of grassland type around the County. Particularly important within Devon is a high concentration of wet, acidic pasture - comprising a mix of grassland and mire communities - known nationally as ‘Rhôs Pasture’. Its strongholds are on the poorly drained soils of the Carboniferous shales and sandstones of mid and north-west Devon - formerly known as the ‘Culm Measures’ and where it is referred to as ‘Culm Grassland’ - and in valley systems on Dartmoor. Further concentrations of unimproved grassland are found along Devon's two coastlines, although the lack of management in many areas results in these grassland communities forming a mosaic with bracken and scrub. The majority of these coastal grasslands are broadly similar to those found inland, but the salt-laden winds and exposure of the extreme coastal fringe result in characteristic grassland communities referred to as maritime grassland, typified by species such as thrift and buck's-horn plantain.

Although not widespread in Devon, calcareous grassland communities are associated with the limestone outcrops found in isolated pockets across the south of the County from the undercliffs at Axmouth in the east to Plymstock in the west, with these being particularly well developed on the headlands which enclose Torbay. At the opposite end of the pH scale, acidic grasslands are particularly associated with the upland areas within, and adjacent to, Dartmoor and Exmoor, these often occurring as extensive stands on common land alongside areas of bracken and scrub and resulting from the heavy grazing of heathland communities. The types of grassland that are the most highly fragmented, and probably also the most threatened due to the relative ease with which they can be agriculturally improved, are species-rich meadows and pastures associated with neutral (or mesotrophic) conditions which are generally confined to small and isolated fields on marginal farmland.

1.4 Heathlands and mires

The heathland environment comprises a range of specific habitat types for which Britain has an international conservation responsibility due to their very restricted European and global distribution. Although commonly found on thin and infertile soils, heathland vegetation (with its associated mire or bog communities) shows a considerable degree of variation based on topographical and climatic conditions. This is evident not only at a national scale, with Devon supporting a distinctive range of heathland communities which reflect the mild and oceanic conditions of the area, but also within the County where a clear distinction in heathland types is based upon their altitudinal position.

The upland commons of Dartmoor and Exmoor hold the most extensive tracts of semi-natural vegetation found in southern Britain, with these dominated by large and nationally important areas of heather (and grass) moorland, blanket bog and valley bog. These habitats are home to a correspondingly important array of associated species including those at the southern extremity of their breeding range, including waders such as dunlin and golden plover, and others with national strongholds in this location, such as the high-brown and heath fritillary butterflies. The upland mire deposits of Dartmoor and Exmoor are also important for their waterlogged cultural material and palaeoenvironmental record (i.e. buried material, such as pollen and plant micro fossils, used in the reconstruction of past environments) which enable the study of historical vegetation cover and land use.

Devon also holds an important concentration of lowland heath communities, these comprising species such western gorse and bristle bent which are strongly western in their distribution and supporting a distinctive fauna including national rarities such as the Dartford warbler and southern damselfly. These lowland heaths are found in just a few parts of the County, with the largest unit located on the east Devon commons but with other significant concentrations occurring on the Haldon Ridge, within the Blackdown Hills and Bovey Basin, at various coastal locations (which include maritime heathland communities), particularly on Lundy, within Exmoor National Park and in other parts of northern Devon, and forming transitions with upland communities on the edges of Dartmoor and Exmoor. There is a very blurred distinction between heathland and other similar communities on the Carboniferous ‘Culm’, where the term Culm Grassland has been used to embrace all such habitat types.

1.5 Freshwater

This range of habitat types includes all those areas with open freshwater, be it still or running, or a degree of water-logging giving rise to wetland communities such as swamps, fens or flushes. Many of the County's wetland and freshwater habitats, other than streams and rivers, owe their origin to the activities of man through the deliberate creation of reservoirs, ponds and canals or as a by-product of commercial activity, such as mineral extraction.

There is a very extensive network of flowing waters within Devon, with one of the most striking features of this being the concentric pattern of many of these rivers resulting from their origin on the highland mass of Dartmoor. Exmoor and the Blackdown Hills also form the source for a number of river systems. The upper reaches of many Devon rivers are nutrient-poor and fast flowing, giving rise to a very distinct character typified by the general absence of macrophytic vegetation and the frequency of birds such as dipper and grey wagtail. The mid and lower reaches display a wide range of conditions and, on the whole, retain a relatively natural character and support important assemblages of riverine species. Many Devon rivers are noted for their salmonids, although fish such as bullhead and shad are also of particular conservation significance. Several river systems, particularly the Taw, Torridge and Tamar, also provide a national stronghold for otters.

Devon is not especially noted for its open standing waters although artificial lakes, ponds and reservoirs are common and often of considerable significance for wildlife; for example, a particular concentration of ponds within the Bovey Basin, resulting from the past extraction of ball clay, support an important assemblage of dragonflies and damselflies. While natural lakes are similarly not a feature of the County, Slapton Ley is a notable exception and one which is of particular conservation significance. Swamp, fen and inundation communities are now thinly scattered across the County, with many of these having been lost through drainage or neglect, and are typically associated with open water areas, spring-line sites, in valley bottoms in the lower reaches of the main rivers and around tidal limits in some estuary systems. Many of the significant reed beds within Devon are associated with tidal or brackish, rather than truly freshwater, locations One of the species which is found in nationally significant numbers associated with wetlands sites in Devon is the Cetti's Warbler, this having strongholds at Slapton Ley and around the upper Exe Estuary.

1.6 Coastal habitats

The geological and topographical variation along Devon's two coastlines contributes to an outstanding assemblage of coastal habitats which collectively make up one of the most important elements of the County's wildlife resource. Although only a relatively narrow zone, the length of the coastal strip [i.e. from the cliff-line to mean low water) within Devon means that it contains some 5.5% of the total area of wildlife habitat, with an important element of its character being the widespread occurrence of natural, as well as semi-natural, vegetation communities. The coast also marks a fascinating transition from the terrestrial to the marine environment, causing tremendous complications in the classification and mapping of maritime habitats. An additional interest relates to the palaeoenvironmental information which survives within buried organic matter in maritime and intertidal locations and provides important evidence for geologically recent environmental and vegetational changes.

Rocky shores occur around the great majority of Devon's coast, although the character of the inter-tidal communities that they support is largely dependent upon the nature of the substrate and the degree of exposure. As a result of wave action and an unstable boulder shore, inter-tidal communities along much of the northern coastline have a reduced species richness and are dominated by barnacles and limpets with sparse seaweed cover. Conversely, where extensive reefs run parallel to the shore, such as at Wembury Bay on the southern coastline, the partial shelter from the prevailing wave action allows a very wide variety of seaweed and animal communities to develop, with the occurrence of additional habitats such as overhangs, gullies and rock pools adding to this diversity. One of the notable marine communities which is found in places within the inter-tidal zone of the Devon coastline is the honeycomb worm reef which is formed by the reef-building polychaete worm *Sabellaria alveolata*. Colonies of this species can develop into extensive sheets, hummocks or reefs (such as at Ladram Bay on the East Devon coast) which are significant not only in their own right, but also for the manner in which they can stabilise sediments and increase the local habitat and associated species diversity.

Parts of the Devon coastline - most notably in Start Bay and eastwards from the Exe Estuary - have shingle or pebble shores which provide an extremely harsh environment to which only few species are adapted. Sandy conditions are concentrated into three discrete areas at the mouth of the Exe Estuary, in Torbay and on the north coast from Westward Ho! to Woolacombe. Other coastal

habitats resulting from sediment deposition are inter-tidal mud flats and saltmarsh, these being found almost exclusively in the estuarine environment within Devon.

Above the high water mark there is a further set of coastal habitats which include sand dunes and cliffs. Braunton Burrows is one of the largest dune systems in Britain and illustrates the full range of dune communities from the wide sweep of the sandy foreshore through to the variably-flooded dune slacks and associated areas of grassland and scrub. Elsewhere in the County, small dune systems occur at Northam, Instow, Croyde, Woolacombe, Bantham, Exmouth and Dawlish Warren, all of which support rich floras. The latter includes many rare and notable species such as the sand crocus which, in mainland Britain, is unique to Dawlish Warren. Cliffs also exhibit great variation in the plant communities which they support and possibly form the only remaining truly natural terrestrial habitat in Devon. More than being of interest only for their plant communities, cliff lines are often home to a huge variety of invertebrate life, from butterflies to mining wasps and in some locations the hard rock cliffs support important colonies of breeding seabird including guillemots, kittiwakes and razorbills.

Many of these coastal habitats and their associated species are particularly well represented on and around the island of Lundy, this being recognised by its designation as a Site of Special Scientific Interest and National Nature Reserve and Marine Nature Reserve and its status as a Special Area of Conservation. The only other islands of any significant size around the County's coastline are Burgh Island at the mouth of the River Avon, the Great Mew Stone off Wembury Point and Drake's Island within Plymouth Sound.

1.7 Marine mabitats

Although hidden from general view, the wildlife of the sub-tidal environment is no less diverse or special than its terrestrial counterpart; indeed, the richness and variety of Devon's marine life is probably unsurpassed anywhere in Britain. The south westerly location of the County, and its position at the transition between the cold Boreal and warmer Lusitanean biogeographical provinces of the north-east Atlantic, means that a number of typically Mediterranean animals such as cup corals coexist with species of a more northerly distribution.

There is very considerable variation within the sub-tidal communities associated with shallow rocky areas. The upper portion of this 'sub-littoral' zone frequently holds dense stands of kelp and

foliose red algae; the 'kelp forests' found along parts of the Devon coastline, including those in Plymouth Sound and around Start Point, Salcombe and Lundy are notable for the frequent occurrence of the southern kelp species *Laminaria ochroleuca*. The slightly deeper areas are dominated by animals rather than by algae, with this habitat being particularly interesting in sheltered coastal areas, such as within Torbay and Plymouth Sound, where gullies and submarine cliffs and ledges formed out of the limestone bedrock are covered by populations of solitary sea squirts and sponges, while adjoining areas of sediment hold rich and varied mixtures of burrowing species.

An exceptional marine habitat found in Torbay in one of its few UK locations is a network of limestone caves, many of which are submerged below sea level. The reduced light levels here prevent the growth of seaweeds; instead, the caves hold a wide range of filter-feeding organisms, with normally sub-tidal species found within inter-tidal locations due to the dark and humid conditions. Similarly impressive displays of marine life are also found on offshore reefs, particularly within Lyme Bay, where rich and highly diverse climax reef communities hold sponges, anemones, cup corals, Ross Coral and sea fans. Many of these species are erect, fragile and long-lived, with several of these found here at the north-eastern edge of their Atlantic range. These reefs act as important nursery and feeding grounds for commercially important fish and shellfish species. The marine communities found around the rocky shores of Lundy are particularly noted for their diversity which reflects the wide range in exposure to wave action and tidal streams coupled with the variation in the topographical features, rock and sediment types. Many communities also include southern Lusitanean species that have rarely, if at all, been recorded elsewhere in the British Isles.

Sediment plains are a common sub-tidal habitat that often extend over large areas of the sea bed; indeed, these are believed to cover some 80% of Devon's sub-tidal environment, comprising sand, mud and gravels. The soft sediment communities found around parts of the Devon coastline, particularly in Lyme Bay, are notable for two reasons: firstly, for the full and diverse range of substrate types and secondly, for the very high abundance of constituent species. These factors result in an exceptional biomass in certain locations such as Torbay. Where conditions are favourable in shallow waters the marine grasses of the genus *Zostera* can survive and reproduce and sometimes result in extensive areas of 'eel grass beds' or 'meadows'. These form the basis for interesting and important marine communities due to their high productivity, stabilising effect and the shelter and substratum it provides for many species. A

particularly notable sub-tidal expanse of eel grass in Torbay is unusual because of its open coast situation; another important area for eel grass beds is within the Exe Estuary where it forms an important food source for wintering wildfowl when exposed in inter-tidal locations.

A further interest of the marine environment is its mobile (or pelagic) species associated with the open sea. There are frequent sightings and strandings of long-finned pilot whales, Risso's dolphins, common dolphins and bottle-nosed dolphins around Devon's coastline and the South Devon coast is considered to be of national importance for its summer use by Basking Sharks - the largest fish found in UK waters. Other notable mobile species include marine turtles, wintering diving birds and a breeding population of grey seal on Lundy and the Exmoor coast.

The nature conservation significance of the County's marine communities is demonstrated by the fact that of the 27 areas which have been identified by English Nature (now part of Natural England) as being of particular importance for marine wildlife around the coast of England, seven of these are found around Devon.

Important Areas for Marine Wildlife in Devon
Lyme Bay
Exe Estuary
Torbay to the Dart Estuary
Bolt Tail to Slapton (including Salcombe estuary)
Plymouth Sound, Tamar and the Yealm (including Wembury)
Lundy
North Devon: Ilfracombe to Combe Martin

Source: Important Areas for Marine Wildlife around England (English Nature)

1.8 Estuaries

Estuaries are particularly well represented within Devon, with these forming an important and integral element of the coastal and marine environment. Not only do these have a rather inequitable distribution in the County, with 10 of the County's 11 estuaries (including the Devon portion of the Tamar complex) found along the southern coastline, but they also exhibit marked variations in character from the steep-sided rias (or drowned valleys)

characteristic of the South Hams to the wide sweeps of the Taw-Torridge and eastern estuaries where major river systems discharge into the sea. These estuaries form the interface between two forms of aquatic life: the riverine and the marine. This results in a complex and dynamic environment, but one that is also highly productive due to the continual input of nutrients and sediments from both sea and land.

This productivity accounts for the importance of Devon's estuaries as a wintering ground and staging-post for migratory water birds which congregate to feed on the huge populations of worms, molluscs and other invertebrates which are found within the inter-tidal mud and sandflats. Two of Devon's estuaries, the Tamar/Tavy and the Exe hold internationally significant numbers of water birds, with this latter site supporting in excess of 6,000 wildfowl and 15,000 waders, including the largest flock of avocets in Britain outside of Suffolk.

Saltmarshes are, perhaps, the best known and characteristic plant communities found within the estuarine environment which, together with stands of inter-tidal reed and areas of coastal grazing marsh, are only extensively found within the Taw-Torridge and Exe estuaries. The marine communities of estuaries are also of considerable wildlife significance, with these being particularly important and well represented within the Salcombe and Kingsbridge estuary due to the minimal freshwater flow. Three species of fish, the flounder, grey mullet and sea bass, are particularly associated with estuaries, with Devon providing the most important nursery areas in the country for this latter species.

1.9 Farmland habitats

The prevalent land use over the great majority of the County - accounting for more than 80% of the land surface area - is farming. Although modern agricultural practices have led to the widespread replacement of semi-natural plant communities by commercially important and cultivated species, various features of the farmed landscape remain of vital importance to Devon’s wildlife interest.

Farmland provides the main habitat for many species of bird such as skylark, grey partridge, song thrush and linnet, with lowland areas of mixed farmland with extensive (i.e. low intensity) production providing particularly favourable conditions. This connection between bird populations and lowland, extensive, mixed farmland is well demonstrated in Devon by the cirl bunting which appears to be dependent upon permanent pasture with high insect populations

during the summer months and areas of rough ground, particularly stubble fields resulting from spring-cropping, rich in weed seeds during the winter period.

Such farmland also provides suitable conditions for an important but, hitherto, largely neglected part of our native flora, collectively referred to as 'arable weeds'; this includes plants such as corn marigold or round-leaved/sharp-leaved fluellen which are found in cultivated or disturbed land that is not subject to frequent applications of inorganic fertilisers and herbicides. Lowland farmland also provides the main habitat for a number of our mammal species such as brown hare and harvest mouse. Other valuable habitats on farmland include old orchards, areas of scrub or tree cover, ponds, and even old farm buildings which may provide roosts for owls, bats and other creatures.

One of the most obvious features of the farmed landscape which is of considerable importance for wildlife is Devon's impressive network of hedgerows. Many of the County's hedgerows are of great antiquity, with perhaps a quarter of these being in excess of 800 years old and, as a result, often hold a rich assemblage of plant and animal life. Indeed, Devon's hedgerows are of crucial importance for a number of nationally rare species including the dormouse, horseshoe bats and brown hairstreak butterfly and a number of scarce plants such as bastard balm and balm-leaved figwort.

1.10 Urban habitats

Devon's wildlife is not confined to rural areas and the marine environment but instead extends into the very hearts of our cities, towns and smaller settlements. A wide range of habitats of value to wildlife are found within the urban environment; in many cases these constitute fragments of previously rural habitats, such as grasslands, woodland and wetlands, which have become isolated as a result of urban expansion. Recent surveys and biological recording within Plymouth, Torbay and Exeter have shown all three of the County's major urban centres to be outstanding places for wildlife. More than a third of Devon's rarest plants are found on the limestone outcrops in Plymouth and Torbay, including national rarities such as Little Robin, White Rock-rose and Goldilocks Aster, and much to people's surprise and excitement, species such as salmon, otter and nesting peregrines can be encountered within sight of Exeter's city centre.

The wildlife of urban areas has also found a new niche by adapting to the conditions provided by redundant industrial land, parks, railway lines, allotments and churchyards. Even private gardens can provide havens for wildlife and bring people into daily contact with nature. Greater environmental awareness has meant that such areas are increasingly being managed to benefit their wildlife interest or are being established as a new and positive use through the restoration of redundant or derelict land. However, development pressure remains a constant and very real threat.

Particular importance is placed on features which act as wildlife corridors, facilitating the regular movement or migration of species into and around the urban environment and which provide a link between otherwise isolated areas of habitat. This concept has been developed in Exeter through its series of 'Valley Parks' and in Plymouth such features are identified and protected through the Local Plan. A vitally important aspect of many urban wildlife sites is the opportunities that these afford for public amenity and education, providing a clear link between the great majority of Devon's residents and the natural environment around them, thereby contributing greatly to their quality of life.

2. An Overview of Devon's Species

2.1 Species diversity in Devon

An exceptional range of species is associated with Devon's land, freshwater, coastal and marine habitats. Indeed, few other English counties can boast such a wealth and diversity in their native wildlife. Although this reflects the extent and importance of the County's habitats, as described in the preceding section, there a number of underlying factors which account for this richness, diversity and special attributes of Devon's species.

Devon benefits from a great variety of geology and landform. These, in turn, provide an almost unrivalled range of ecosystems and ecological niches from those associated with its coastal waters and shores, through to its lowland and freshwater habitats and on to the upland environments of Dartmoor and Exmoor. It is this variation in conditions that enables so many species which are at the edge of their geographical ranges to coexist in Devon, with unusual combinations such as dunlin and golden plover at the southern extremity of their European breeding range and the sand crocus at its most northerly outpost.

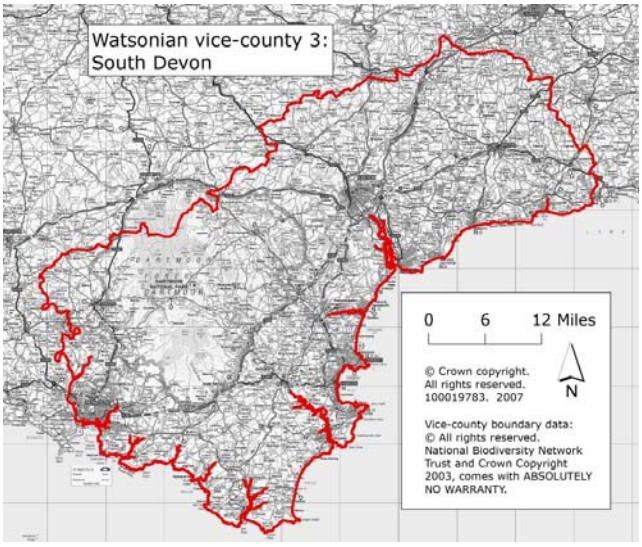
The diversity in marine life in Devon's coastal waters reflects the great variety of conditions found along the two contrasting coastlines and the mixing of cold northern and warmer Mediterranean waters, each with their own characteristic wildlife forms.

The geographical position of the County on the western Atlantic seaboard with its oceanic climate results in a distinctive array of 'Lusitanean' (or western) species. Notable examples include whorled caraway and wavy-leaved St. John's-wort, both of which have national strongholds on the culm grasslands of north-west Devon, and commonplace plants such as western gorse which give a particular character to the vegetation communities typical of the County. It also partly accounts for the good representation in the County of groups such as lichens, mosses and liverworts.

2.2 Notable and characteristic species

Species of particular conservation priority and concern in Devon are listed in Appendix i. This list is derived from those drawn up through the national biodiversity action planning initiative and recognises the status of the constituent species as globally threatened or declining. Of 34 UK endemic species highlighted in an audit of the biological resource of the South-West**,** 16 are found in Devon. Three of these, including the Lundy cabbage, are believed to be found nowhere else.

It is worth noting that the southern half of Devon (i.e. vice-county 3 - see map) has a particularly rich and varied flora, with only a handful of other vice-counties holding a greater range of nationally rare and scare species. A high proportion of these are associated with outcrops of limestone in Torbay, Teignbridge and Plymouth and the East Devon chalk, despite the very restricted occurrence of this rock type.



Devon is also notable for holding the richest bryophyte flora of all English counties and is exceptionally rich for lichens. Although impossible to generalise, of equal note are elements of Devon's fauna. Notable examples of species for which Devon has a

particular conservation responsibility include the cirl bunting, whose British breeding population is currently confined to the County, the blue ground beetle, a species once thought extinct and only re-discovered in Devon in the 1980s and pink sea fan, which has important concentrations on the offshore reefs of Lyme Bay and in Plymouth Sound.

It is not only the rare and threatened which form important element's of Devon wildlife and are deserving of conservation attention. It is the full range of our native species which make up the biodiversity of the County and from which it derives its natural character. Examples of typical or characteristic species which are much admired in Devon include the spring-time displays of primrose and early purple orchid on our roadside verges, the soaring buzzards overhead and the dancing flight of butterflies such as the marbled white. It is important that proper attention is given to the conservation of characteristic and commonplace elements of our wildlife, so that Devon retains the uniqueness, diversity and attractiveness of its natural environment.

Appendix v lists those Devon species which, by virtue of their rarity, vulnerability or persecution are given some form of special protection through wildlife legislation.

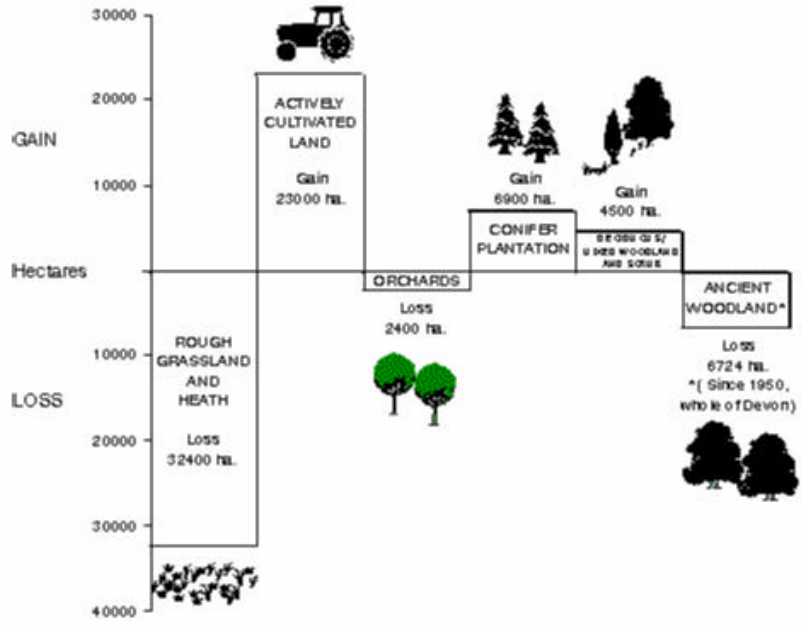
3. Changes in Devon's Wildlife

3.1 Habitat loss: historical and recent

Studies carried out at a national level have shown that substantial changes to our wildlife heritage have occurred throughout the 20th Century, with some of the most rapid changes taking place in the post-war era. Whilst there is no specific and comprehensive research which has been carried out in Devon to identify all of the changes that have occurred here, a number of studies have been undertaken which do confirm that the trends in Devon are similar to those for the country as a whole.

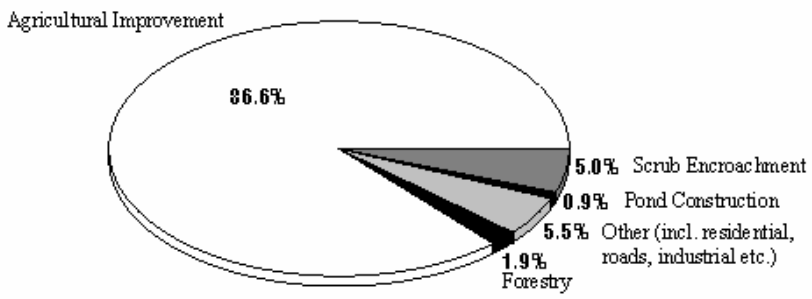
The 'Changing Face of Devon' project undertaken by Devon County Council and the Nature Conservancy Council in 1979 documented the major changes in the extent of some of the principal land uses and habitat types in Devon between 1905 and 1978. Although this information is now dated, the changes which took place within this period were of such a scale and reflected such significant shifts in agriculture, forestry and urban and industrial development, that they set the scene for present-day nature conservation in Devon.

Net Changes in the Extent of Major Habitat Types in Devon (excluding national parks) between 1905 and 1978



More recent studies have shown that loss and damage to some of our most valued habitats has continued. A prime example of such work is the Devon Culm Grassland Survey undertaken by the Devon Wildlife Trust and English Nature (now part of Natural England). This revealed that of a total of 626 sites known to have previously held Culm Grassland communities, 383 (or 61%) of these were wholly lost between 1984 and 1991. In terms of land area, 48% of Culm Grassland was lost over this period, although the figure rises to 65% if Sites of Special Scientific Interest are removed from this analysis. Although recent initiatives - particularly the targeted use of grant incentive schemes such as Countryside Stewardship - have secured the conservation and sympathetic management of over two-thirds of the total remaining area of Culm Grassland in Devon.

Reasons for the Loss of Unimproved Culm Grassland between 1984 and 1990/91



(Source: Devon Culm Grassland Survey)

Even in our most strongly protected and valued landscapes, such as National Parks, there have been continued threats to wildlife habitats. A repeat survey of rhôs pasture habitat within Dartmoor National Park [Hughes, M R, 1995] showed that many sites were suffering from scrub encroachment and were in need of positive management. Conversely, heavy grazing and/or frequent and extensive burning has resulted in much upland heathland on Dartmoor being lost to grass moor and where heather does occur it is often suppressed and does not realise its full potential for nature conservation.

Although there are few data available from which to assess the loss of marine habitats around Devon's coastline and coastal waters, a recent study undertaken by the Devon Wildlife Trust within Lyme Bay [*DWT, 1993*] clearly documented the nature conservation importance of its inshore reefs and the damaging impact that the use of mobile fishing gear has had upon these. Other threats to the marine environment which are readily apparent within the County result from pollution, including both chronic and acute oil pollution, mineral and aggregate extraction, disturbance from recreational activities, the introduction of alien and invasive species, marine developments (such as the reclamation of estuarine mudflats and coastal defence works), over fishing and by-catch problems and from marine dumping.

3.2 Species Loss

Any changes in the extent and quality of wildlife habitats are likely to have a corresponding effect upon the populations of individual species that they support. Indeed, the same general trend of decline is evident for many of the species for which records have been documented over the last few decades. This decline can be illustrated by a review of changes in the status of the 45 species of butterfly which can be considered to have been resident or regularly breeding in Devon in the last few decades:

Changes in the status of Devon butterflies since 1960 (date: 1998)	
Nature of Change in Status	Number of Species Affected
Decline in status	13
Extinction as resident/regularly breeding species	3
Increase in status	1
No significant change in status	17
Insufficient information available	11

Based on:Devon Butterflies, RSNC Guide to Butterflies of the British Isles and communication with Butterfly Conservation (Devon).

3.3 Habitat Creation and Wildlife Enhancement

At the same time that wildlife losses have occurred in the County, so too have there been gains, although it is important to consider the precise nature of these changes. Figures provided by the Changing Face of Devon (Turnbull & Nicholson, 1979) study clearly demonstrate that there have been gains in the extent of broadleaved woodland and scrub. Although this provides new wildlife habitat, this only brings about a net benefit where these habitats are being created on land that does not already posses significant wildlife interest. The information on habitat loss and change presented above demonstrates that part of this gain in scrub and woodland has been at the expense of valuable 'open' habitats such as heathland and unimproved grassland, both as a result of natural succession and the deliberate planting of trees.

In recent years, there has been an increased recognition of the potential value of, and need for, creation and enhancement of wildlife habitats which has resulted in significant conservation benefits. Notable are the habitat creation schemes which have increasingly been integrated into major development proposals such as in the restoration of mineral extraction and waste disposal sites, and wildlife projects that have been funded through various conservation grant and management agreement schemes. At a broader scale, changes in agricultural and forestry policy and support have resulted in very considerable benefits for wildlife, both directly (such as through the designation of Environmentally Sensitive Areas) or as a spin-off from other policy objectives (as has been the case with the set-aside of arable land in certain situations). Some of the most beneficial forms of wildlife enhancement, however, are those which aim to restore the wildlife interest of existing wildlife habitats, particularly where these have deteriorated due to poor management. The development of

national and local grant-aid and other financial schemes - particularly Countryside Stewardship - have had considerable success for certain targeted habitats types such as Culm Grassland or lowland heath. This scheme has now been replaced by Environmental Stewardship (2007). Similarly, the Dartmoor rhôs pasture initiative has also used management agreements to fund positive works such as scrub control and the re-introduction of grazing on important sites.

Listed below are some of the main habitats which have particularly benefited from habitat creation - intentionally or by default - in the County in recent years.

Habitat type	Major influence on habitat creation
Scrub	• Neglect of marginal agricultural land
Woodland	• Natural succession on areas of semi-natural habitat (esp. heathland) • National and local grant-aid and tree planting schemes. • Commercial afforestation. • Restoration of mineral and waste disposal sites • Landscape planting associated with new developments.
Pond, lakes and other wetland habitats	• Creation of public water supply reservoirs (esp. Roadford), National and local grant-aid schemes • Restoration of mineral extraction sites • Flood-defence programme • Storm-drainage provision for major developments
Roadside verges	• Highway construction programme
Uncultivated agricultural land	• Agri-environment schemes
Hedgerows	• National and local grant-aid schemes • Mitigation measures in development schemes

In addition to schemes which have promoted the creation and enhancement of wildlife habitats, considerable effort has also been put into enhancing the populations of certain species. This has been done at both a very general level, for example through the widespread promotion and use of nest boxes, and in a very much more organised and scientific manner, such as through English Nature's 'Species Recovery Programme'. Examples of rare and threatened species which have been specifically targeted for

conservation attention in Devon in recent years include the cirl bunting, Plymouth pear, strapwort, dormouse, large-blue butterfly and greater horseshoe bat. This targeted approach is now being strongly reinforced through the biodiversity action plan process.

4. Devon's geological heritage: an introduction

4.1 Devon's geological history

The Earth heritage resource displayed within Devon is one of the most varied in the British Isles and this is reflected in the great variety of its landscape. The County records around 410 million years of Earth history and is particularly distinguished by being the only one in the British Isles to give its name to an interval of geological time of world-wide recognition - the Devonian Period. The relationship between the varied bedrock of the County and its landscape is also more faithfully represented in Devon than in many more northerly areas, as it remained essentially unglaciated during the Pleistocene 'ice ages' and consequently was not either levelled by ice sheet erosion or blanketed by glacial deposits as the ice melted. Nevertheless, the development of permafrost conditions created a wide range of periglacial features and deposits and fluvial and coastal processes have created important landforms and other features.

Devon's geological deposits range in age from the ancient slates of the lower part of the Devonian Period, around 410million years ago, to the most recent and still accumulating sandy and muddy deposits of its rivers and coastline. A summary of Devon's geological history is given below, with the present day distribution of its bedrock geology illustrated by Figure 2.2.

The oldest rocks in both North Devon and the South Hams date from the **Lower Devonian** and are aged from around 410 million years. These sediments were laid down on coastal plains possibly in lakes and river systems and very locally contain the remains of primitive armoured fish (the Dartmouth Group of South Devon). Sea levels gradually rose and by around 407 million years ago marine conditions had spread across the region, often including shallow water sandy deposits with marine shells such as brachiopods and even rare woodlouse-like trilobites (including the Meadfoot Group of South Devon). In North Devon the muddy and sandy Lynton Group appears to represent late Lower Devonian shallow water sediments deposited close to the margin of the arid landmass of the so-called

'Old Red Sandstone continent' that occupied more northerly areas of Britain throughout the Devonian Period.

The sea continued to deepen and muddy conditions became widespread in more southerly areas during the early **Middle Devonian**, around 395 million years ago. These deposits are now represented by the dark slates in Torbay and south of Plymouth. The subsidence which caused this deepening was related to continental stretching as Plate Tectonic movements created an ocean to the south of Britain. A by-product of this activity was the creation of a series of east-west marine basins with relatively shallow water 'rises' between. By the later Middle Devonian, around 392 to 385 million years ago, extensive reef belts dominated by coralline sponges had developed along these ridges. These reef and associated shallow tropical sea deposits often contain rich fossil faunas, some of which were used to first characterise the Devonian time period in the mid to late nineteenth century. They are dominated by the thick limestone deposits which now outcrop between Torbay and Plymouth. Locally volcanic activity was also significant. In North Devon, although the early Middle Devonian includes the sandy river-lain deposits of the 'Hangman Grit', some limestone bands with corals and shells are associated with the sandy and muddy shallow water deposits of the Ilfracombe and Coombe Martin slates.

By the early **Upper Devonian**, around 385-375 million years ago, even the shallower water rises had sunk into deeper waters and muds were being widely deposited in more southerly areas, as now represented by slates south-east and west of Dartmoor. A victim of these changes were the reef systems, which were smothered as they subsided into deeper waters – their rich coral and shelly faunas passing into deeper water deposits, locally with the spiral shells of early ammonoids – an extinct group of cephalopod molluscs related to squids. In North Devon, although the earliest part of the Upper Devonian includes the Morte Slates, the proximity of the 'Old Red Sandstone' continent is indicated by near-shore sands of the 'Baggy Beds' and the plant bearing non-marine 'Pickwell Down Sandstone' which has yielded some of the earliest known seed plant remains in Britain.

Deep marine conditions continued into the **Lower Carboniferous**, around 359 million years ago, which is marked by the extensive volcanism in West Devon which produced the distinctive green ash of which most of the centre of Tavistock is constructed, and the lavas which form the distinctive knoll of Brentor.Associated in both north and south Devon are thick deposits of chert, a hard siliceous rock deposited in deep water, and dark slaty shales – the former is

particularly prominent south of Barnstable where it forms the Codden Hill ridge. Few fossils are found in these rocks, although locally ammonoids and trilobites are common. In north-east Devon in particular, bands of limestone are also present and often represent lime mud and debris washed into the deep basin from shallow water areas to the north-west where thick deposits of Carboniferous limestone are well developed, as in the Mendips. Their deeper water equivalents have been extensively quarried in the Bampton and Westleigh districts.

By the **Upper Carboniferous**, around 318 million years ago, earthquakes associated with the rise of a mountain chain to the south dislodged sands and muds on the sides of the marine basin, which then flowed into deeper areas in turbid currents. As the speed of the current dropped as it reached gentler slopes towards the bottom of the basin, the sands settled out of suspension followed by the muds. This process repeated countless times, eventually forming the alternating sandstones and shales of the well known 'Culm Measures' of mid and north-west Devon – and known more correctly as the Crackington Formation. In north-west Devon a coastal lake developed inhabited by fresh water mussels and plant remains locally accumulated to form sooty coal – these deposits being of equivalent age to the 'Coal Measures of South Wales and the rest of Britain. These are the deposits of the Bideford Formation, a lateral equivalent of the thick sandstones of the Bude Formation, the youngest deposits of the Carboniferous in Devon. The Crackington, Bideford and Bude Formations, together with the shales of the Lower Carboniferous below all give rise to typical Culm Grassland habitats.

The Lower Carboniferous in the region is marked by the beginning of the tectonic activity which climaxed with intrusion of the Dartmoor granite magma close to the Carboniferous-Permian period boundary. This activity, the **Variscan Orogeny**, was a direct consequence of the tectonic plate collision of Africa with Europe. Sediments which had accumulated in ocean basins between the continents were squeezed up and thrust over each other as great slices known as 'nappes', to form a huge mountain chain, running from eastern North America (which was joined to Europe at the time), through Cornwall and Devon to Belgium, the Czech Republic and beyond. By around 300-290 million years ago, the Variscan Mountains had been piled so high that their base sank so far into the Earth that it melted to form a magma. This magma was then intruded into the upper layers of the crust and solidified as **granite**, Dartmoor being the most easterly and largest of these intrusions in south-west England.

The extreme heat of the granite literally 'cooked' the rocks it came into contact with as it was emplaced, producing a **metamorphic aureole** around a kilometre wide. Fluids leaking from the granite contributed to this process by reacting with the surrounding 'country' rocks, locally producing a remarkable range of metamorphic minerals including garnets. During the final stages of its crystallisation, small pockets of fluids rich in rarer elements such as lithium accumulated before being injected as veins into the aureole. The most remarkable of these is the Meldon Aplite, near Okehampton, which has long been known as a source of rare and unusual minerals. In south-west Dartmoor, the granite released fluids that began to react with itself, decomposing its component feldspar crystals to form china clay.

The heat of the granite also produced vast convection cells in the surrounding country rocks as superheated water circulated, leaching metals from the sediments and associated volcanic rocks. These fluids were subsequently injected into cracks in the cooling granite and surrounding rocks and minerals crystallised out to form the copper and tin-rich mineral veins. Over 10s of millions of years as cooling continued, lead, zinc and other ores were also deposited. These **mineral deposits** have long been of economic importance in the County, perhaps back to pre-Roman times, and were the raw material that fuelled the mining boom of the late eighteenth and nineteenth centuries.

This Variscan Orogeny event had a very fundamental effect on the Devonian and Carboniferous rocks of Devon and was responsible for their intense folding and faulting. From Dartmoor southwards, the northward transported or 'allochthonous' nappe dominated geology is often highly complex with slices of Devonian and Carboniferous rocks of different ages shuffled together. The 'Culm Basin' of mid Devon, however, although strongly folded and faulted by the compression associated with the continental collision – as spectacularly seen on the coast around Hartland Point - is more or less where it was originally. Similarly, the sequence of Devonian and Lower Carboniferous deposits in north Devon is much less disturbed than its equivalents in the south of the County.

The southernmost tip of Devon, however, between Start Point and Bolt Tail shows a quite distinct geology dominated by relatively 'high grade' metamorphic rocks dominated by schists. These rocks have been subjected to such extreme pressures and high temperatures that they were completely recrystallised. How and exactly where this took place remains unclear, but the **Start Complex** was eventually faulted into place against the nappe terrain of south Devon during the Variscan Orogeny.

The new mountain chain had risen in a desert climate and began to erode very rapidly. By the early **Permian** , around 290 million years ago, stony deposits were accumulating in basins around the mountains, as seasonal flash floods washed loose scree down wadis. These deposits are well exposed in Torbay and also at Peppercombe in north-west Devon and typically form the lowest part of the well-known 'New Red Sandstone' of the County, the red colour being a consequence of the oxidation of iron minerals in the sediments under intense desert conditions. Later in the Permian vast sand dune systems crossed the County, sections in which are most famously exposed in Dawlish Cliffs, but also in Sowton in Exeter. The early Permian also saw volcanic activity between Exeter and Hatherleigh, the lavas formed becoming an important building stone from the Middle Ages, including the 'Exeter Traps'. Very little could survive in these deserts although reptile footprints have been found near Exeter and burrows presumed to have been created by giant millepedes are present in Torbay.

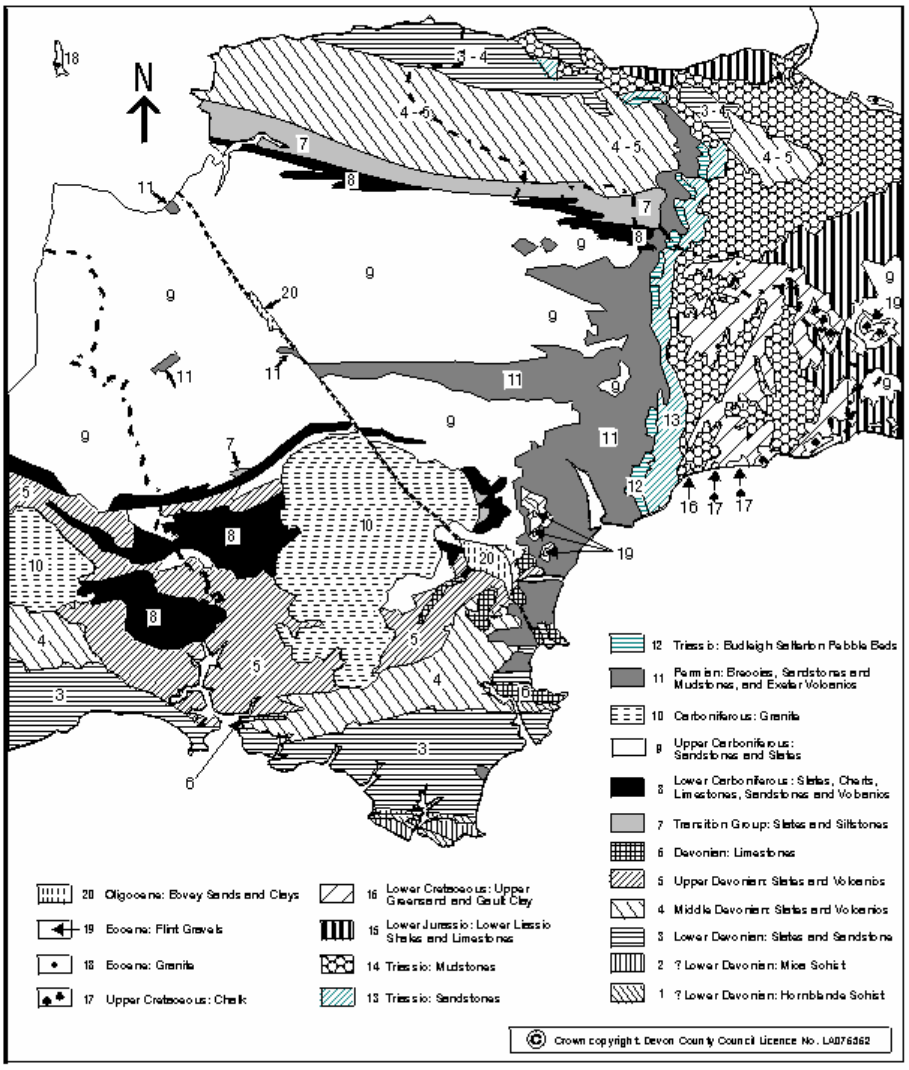
Desert conditions continued into the **Triassic** Period, around 250 million years ago as 'New Red Sandstone' deposition continued. The Variscan Mountains were already very much subdued by erosion and where Triassic rocks are now preserved in East Devon, most deposition was taking place in broad arid basins. Muds were laid down during seasonal floods and even in temporary playa-style lakes but the County's best known Triassic deposits are the Budleigh Salterton Pebble Beds, the product of large, seasonal river systems. Most of the pebbles that these deposits contain are unlike any rock known in Devon and include Ordovician quartzites, potentially carried from as far away as Brittany. Although fossils are generally rare, near Sidmouth bones of primitive reptiles have been found associated with sandy and muddy river deposits.

At the end of the Triassic, around 200 million years ago, the sea flooded across the desert and clays and limestones were deposited in the tropical seas of the early **Jurassic**. These rocks are only exposed in the extreme south east of the County to the east of the Axe Valley, most spectacularly in the cliffs west of Lyme Regis, which are largely within Devon not Dorset. These rocks are famous for their fossils including the spiral shells of ammonites and extinct marine reptiles such as icthyosaurs.

Higher parts of the Jurassic are no longer preserved in Devon and at least by around the end of the Period, around 146 Million years ago the region was land. The sea returned, however, in the late Lower **Cretaceous**, around 112 million years ago cutting across the older rocks of the County and depositing the shallow water sands of the Upper Greensand, with its locally rich shelly faunas. These deposits

are preserved as far west as Newton Abbot but have their most dramatic effects on the Devon landscape where they form the flat plateaux of the the Haldon Hills and the Blackdown Hills as far as the coast around Sidmouth. The sea deepened and limestone deposition took over as countless remains of calcareous plankton accumulated on the sea floor to form the Chalk – each centimetre cubed of which can contain the remains of around 92 million coccolith algae! The Chalk has only a very limited outcrop in the Beer and Membury areas of East Devon, but still forms important calcareous grassland sites. Its cover was once much more extensive, however, as patches of flint gravel left behind after it had dissolved away are known on the Haldon Hills and elsewhere in Devon.

Figure 2.2 THE GEOLOGY OF DEVON



Source : Durrance, E. M. & Laming, D.J.C. - The Geology of Devon - University of Exeter Press

The Chalk sea receded and during the Eocene and Oligocene epochs of the succeeding **Palaeogene** Period, between around 56 and 23 million years ago, the Bovey and Petrockstow basins developed, initially with pebbly river deposits but subsequently with large lakes. The latter accumulated economically important china-clay rich clays washed down from highlands in which the Dartmoor granite was by now well exposed and deeply weathered under the tropical conditions. The Bovey Basin, in particular, often contains evidence of the vegetation of their hinterlands including branches and trunks of giant redwood trees washed down from the uplands. Sometimes this debris is so abundant as to from beds of 'brown coal', or lignite. In the mid Palaeogene the Lundy granite was intruded, an igneous rock with greater affinities to those of the similarly aged volcanic centres of north-west England than anything else in southern Britain. (The Palaeogene and succeeding Neogene periods were formerly combined within the 'Tertiary').

Little evidence remains in Devon of the Neogene Period, which lasted from around 23 to 1.8 million years ago, although it is believed that intense tropical weathering continued producing stony, lateritic soils which are locally recorded in East Devon.

During the Pleistocene Epoch of the early **Quaternary** Period, global temperatures collapsed and during the subsequent ice ages, periglacial permafrost conditions took hold across the County, which largely lay to the south of the maximum extent of the ice sheets. Seasonal melting of the top metre or so of the permafrost during the slightly warmer summers caused loose soil and rock to creep downhill as a stony sludge. Locally, especially in East Devon, large landslip systems developed on the slopes were the bedrock geology was domianted by relatively weak clays and sands. Periglacial processes could eventually expose bare rock on the crest of hills, thereby creating the tors of Dartmoor, but they also lead to the accumulation of thick blankets of clayey and stony 'head' in valleys and on slopes. Many of the important Culm Grassland sites of mid and north-west Devon are likely to be developed over this periglacial head cover rather than directly above Carboniferous bedrock. Most of these deposits are likely to date from the last or Devensian glaciation, which lasted from around 90,000 to 11,000 years ago, as earlier deposits are likely to have been disturbed during the previous interglacial or 'reworked' during this later phase.

The north-west coast of Devon does including some evidence of the proximity of ice, however, as large 'erratic blocks' transported from northern Britain are known around Croyde and clays with a glacial origin are recorded near Barnstable – and formerly worked to

supply a local ceramics industry. There is some debate about these deposits, however, and they may indicate that at its maximum extent of Pleistocene glaciations, around 450,000 years ago, ice sheets may have just touched the North Devon coast.

River erosion during the Quaternary Period gradually created much of the present day landscape of Devon, as it dissected an apparently erosively flattened landscape of the Neogene. This process is recorded as a series of terraces, representing sections of former floodplains left high and often dry as the river system cut down deeper, in part in response to sea level changes. The Exe and the Axe valleys in particular have important river terrace records, the highest of which have been dated back to at least 350,000 years ago. In the Axe valley in particular the gravels deposited on these ancient floodplains are an important source of Palaeolithic stone implements. Near Honiton they have also yielded hippopotamus remains, dating from the last interglacial – the Ipswichsian – around 120,000 years ago.

The limestones of south Devon, in particular, developed cave systems during the warm, moist interglacials of the Pleistocene which then accumulated deposits recording the climate and faunal changes over this dramatic interval. These include interglacial faunas with hippopotamus, forest rhinoceros, straight tusked elephant, hyena, sabre toothed cat and bison and glacial assemblages with mammoth, reindeer, bear and woolly rhinoceros. Devon's caves also record the County's earliest known inhabitants, tools made by a hominid probably close to *Homo heidelbergensis* from Kents Cavern in Torquay.

Changing sea levels associated with the build up of ice sheets and their subsequent melting had a dramatic effect on Devon's coastline. The high stands of the Ipswichian interglacial around 120,000 years ago cut a raised beach around 7m above present sea level, but during the subsequent Devensian ice age, sea levels fell again and the coastline receded some distance away from its present position in many places. As these ice sheets melted, the sea flooded back, drowning over-deepened estuaries to form the County's famous rias. It also rolled a vast bank of shingle landward in south-east Devon as it rose, to form the Slapton Ley barrier. Few places in Britain show these changes as dramatically as the coast near East Prawle, where an ancient cliff line, with a linked raised beach platform, dating from the last interglacial is draped with periglacial 'head' deposits from the succeeding Devensian glacial interval. Above, an earlier platform and cliff-line is visible.

Devon also includes important post-glacial climate records and deposits preserved in peat deposits on its moors but also in estuarine and so-called ‘submerged forests’ along its coasts. These not only record the improving climates as the ice ages ended, they also record subsequent fluctuations of great significance to current discussions of climate change and its causes. Not all of these changes are entirely naturally, however, and these deposits also record human impacts on ecosystems as forests were cleared for agriculture.

Devon’s coasts continue to evolve as geomorphological processes continue today. Complex sediment systems driven by tides and currents dominate estuary systems, sand dunes still evolve where human intervention has been limited and the East Devon coast east of Axmouth is famous for some of the largest coastal landslip systems developed in Europe. Inland rivers erode and deposit, despite attempts at intervention. All these processes have implications for our own society’s interaction with the geological and geomorphological heritage of Devon - whether it be coastal erosion issues or flood alleviation, an understanding of their geomorphological character and significance is crucial to both our own use of the landscape of Devon and that of future generations.

5. Sites and areas of Earth heritage importance in Devon

5.1 The importance of Devon’s geology

A key factor which makes Devon's Earth heritage resource of importance for education and the development of a wider public awareness, in addition to its scientific value, is its accessibility. The double coastline provides extensive and spectacular natural rock exposure, whilst the long history of quarrying and mining has left a legacy of rock exposure within inland pits, quarries and mine waste tips.

The County is also notable for its landforms and active geomorphological processes which are often well preserved or developed. Nationally important examples of landslips, pebble bars, raised beaches, drowned valleys and dune formation are found around Devon's coastlines, while the high granite-dominated upland of Dartmoor shows periglacial features such as tors and block slopes. Both here and in some coastal locations an important record of post-glacial climate change is recorded, charting vegetational and environmental changes over the last 10,000 years.

Many of the features of Devon's bedrock geology and surface landforms and processes are of national and international importance. The former are recognised through selection as Geological Conservation Review (or GCR) sites (see below), as a prelude to formal designation as Sites of Special Scientific Interest under national conservation legislation. The latter have now been listed as part of the Global Geosites programme, a project initiated with support from UNESCO and IUGS (the International Union of Geological Sciences). The GCR selection categories represented by sites in Devon are listed in Appendix ii and the Global Geosites frameworks are described further in Section E.

5.2 The Geological Conservation Review and statutory geoconservation sites in Devon

Many UK geological and geomorphological sites have been fundamental to the development of the Earth sciences globally and as such the duty to protect such sites is considerably more than just a national concern. Site selection for conservation in the UK commenced in the 1940s, but it was not until the late 1970's that such selection was put into a systematic framework by the initiation of the Geological Conservation Review (or 'GCR'). The GCR selected around 3000 sites in England, Scotland and Wales within 97 subject networks, the latter related to specific geological and geomorphological topics (e.g. within stratigraphical, palaeontological, petrological, mineralogical, structural or geomorphological disciplines). Site selection within each subject area – now termed 'Networks' – essentially recognised three classes of site:

- Sites of *international importance (e.g.* stratotypes, type localities, 'classic' sites, etc.)

- Exceptional sites (e.g. with unique, rare or unusual features, also 'Highlights' of UK geology)

- Representative sites *(e.g. showing* characteristic features of the GCR network)

Following selection, GCR sites are legally designated and protected as Sites of Special Scientific Interest (SSSIs) under the provisions of the Wildlife and Countryside Act 1981 and the Countryside and Rights of Way Act 2000 by English Nature and now Natural England. Geological Conservation Review volumes published by the Joint Nature Conservation Committee (JNCC) provide an up-to-date

review of the scientific basis for site selection within each site network and several key volumes are now available for sites in Devon. The JNCC also oversees the process of formally establishing new GCR sites, based on scientifically justified proposals. The GCR process has identified 145 GCR sites in Devon, the great majority of which are now formally notified within 107 SSSIs. The GCR networks recognised in Devon are listed in Appendix ii.

Some GCR sites are included within areas of particular nature conservation value which has led to their declaration as National Nature Reserves (or NNRs) by English Nature (now Natural England). These sites are owned or leased and managed by that agency or another approved body (for instance a Wildlife Trust), and represent some of the best and most fragile examples of Britain's natural heritage. NNRs with key features of geological and/ or geomorphological significance in Devon include Axmouth – Lyme Regis NNR, Berry Head NNR and Slapton Ley NNR.

Local Nature Reserves (LNRs) are areas with nature conservation value with public access and educational and interpretative provision. Natural England approval is required for the declaration of LNRs, which must be owned or leased by a local authority or other approved body. Sugar Loaf Hill and Saltern Cove LNR in Torbay includes the important Devonian and Permian exposures of the Saltern Cove SSSI and is managed by Torbay Coast and Countryside Trust.

5.3 Non-statutory geological sites

In addition to GCR sites, there are a large number of other localities in Devon which are of county or regional significance for geological or geomorphological science. The Devon RIGS (or Regionally Important Geological Sites) Group has now carried out systematic surveys of much of the County on a district by district basis and has produced detailed inventories of such sites, which are now formally recognised as 'County Geological Sites' (sometimes still known as RIGS). These sites are notified to the relevant local planning authority and protected through both local development plans and policies and voluntary agreements. Over 200 RIGS sites have now been recognised within Devon through these surveys, despite County-wide coverage not yet having been achieved. Site information is being digitised and the Group has a web site from which listings can be obtained. A significant number of sites are also described in the Educational Register of Geological Sites in Devon.

An interesting issue is the relationship between the GCR/SSSI coverage and the County Geological Site network. The latter now includes sites of clear national or international importance. The relationship between such sites and the GCR/SSSI network may need to be clarified in due course.

5.4 International designations

Although there are currently no international legal designations analogous to SACs or SPAs for Earth heritage sites and areas many nevertheless have an international dimension to their importance. In some cases this may lead to a listing or declaration within an internationally well established formalised category, such as World Heritage Site. In other cases the significance is primarily scientific, and although no formal title currently exists, listing is still possible within programmes such as Global Geosites.

World Heritage Sites are truly global in their significance and very few areas or sites can meet the criteria for their selection, as defined by UNESCO. They were established following the 1972 *Convention for the Protection of the World Cultural and Natural Heritage* and natural World Heritage Sites include iconic areas such as the Grand Canyon and the Giant's Causeway. Remarkably, Devon has parts of two World Heritage Sites, both with a fundamental geological component: The Dorset and East Devon Coast (often called the 'Jurassic Coast') and the Cornwall and West Devon Mining Landscapes World Heritage Sites. Although not legal designations *per se*, World Heritage designation is a material consideration in town and country planning.

The **European Geoparks** programme is derived from the concept of UNESCO Geoparks as developed by UNESCO's Earth Science Branch in Paris, as a geological equivalent to biosphere reserves. Indeed, all European Geoparks are also considered to be UNESCO Geoparks. The network now includes 29 Geoparks across 12 European countries. As defined in the project:

> "A European Geopark is a territory which includes a particular geological heritage and a sustainable development strategy supported by a European programme to promote development. A European Geopark must comprise a certain number of geological sites of particular importance in terms of their scientific quality, rarity, aesthetic appeal or educational value"

"A European Geopark has an active role in the economic development of its territory through raising the profile of geological heritage, including through the participation of its residents and promoting the development of geotourism. The Geopark should also support environmental education, training and research in aspects of the Earth Sciences and the enhancement of the local natural environment, including through sustainable development policies."

As the Torbay area has a high concentration of important and accessible geological sites and a dedicated management body, the Torbay Coast and Countryside Trust, which provides educational and public awareness programmes, it perfectly fits the criteria for a European Geopark and was accepted into the network in 2007. For further information on the English Riviera Geopark see www.englishrivierageopark.org.uk. As with World Heritage Sites, the designation has no specific legal status, but it does commit network members to adopt a sustainable approach to the management of the geological heritage under their control.

In 1996 the International Union of Geological Sciences (IUGS) with support from UNESCO and IUCN, commenced a project to compile an inventory of the world's most important **Global Geosites**. In part this list would help inform future geological World Heritage proposals, but it would also help national geoconservation programmes by identifying those sites in each country with a truly international value, through scientific consensus. In the UK this programme has been co-ordinated by the British Institute for Geological Conservation (BIGC) in association with ProGeo (The European Association for the conservation of the Geological Heritage). As an inventory of key geological sites had already been carried out by the GCR (see 5.2 above), BIGC produced a list of selection frameworks representing aspects of the UK's geology considered to be of international importance. This list was largely finalised by 2002. A significant number of these frameworks apply to sites in Devon and independently confirm the international importance of the County's geological heritage. They are listed in full in Section E and used as a basis to define the County's key geological features.

The **European Landscape Convention** was ratified in the UK in February 2007, and although not legally binding, is likely to provide a context for landscape scale initiatives. As such it is potentially very significant for certain types of geomorphologically important landscapes and their geological features and processes.

In 2004 the Council of Europe produced a statement on the conservation of geological heritage which, for the first time, provided a framework within which a strategy for the identification and protection of Europe's rich geological heritage could be developed. Key statements from **'Recommendation Rec (2004)3 on Conservation of the Geological Heritage and areas of Special Geological Interest'** are listed below:

- "*Member States should identify, in the areas within their jurisdiction, areas of special geological interest for protection and management by working through and supporting the existing organisations and conservation programmes currently engaged in geological conservation"* (Appendix 2)

- "*The Council of Europe should develop an information and education programme to promote action in the field of geological conservation"* (Appendix 3)

- "*Member States should develop national guidelines for managing areas of geological interest embodying the principles of inventory development, site classification, database development and monitoring, to ensure sustainable use of areas of geological interest through appropriate management*" (Appendix 4)

- "*The Council of Europe should promote and assist integration of European geological conservation by taking actions to ensure that its own programmes recognise the principles and practices involved, and by working directly with the inter-governmental and non-governmental organisations currently active in geological conservation within Europe*" (Appendix 5)

- "*Member States should strengthen existing laws, or develop new laws, to protect areas of special geological interest and moveable items of geological heritage, making full use of existing international conventions*" (Appendix 6)

Whether this recommendation becomes a Convention remains to be seen, but it does represent a milestone in the development of a truly international approach to the conservation and management of European geological heritage.

A second major milestone in the development of geological conservation as a mature subject within global nature conservation effort was established at the IUCN World Conservation Congress, held in Barcelona (Catalunya, Spain) in October 2008. The explanatory memorandum of **Motion CGR4.MOT055 on the Conservation of geodiversity and geological heritage** provides the context and justification for the Motion:

"The main objective of this resolution is to incorporate the conservation of geodiversity and geological heritage into the agenda of IUCN, the main reason being that both are part of the Earth's natural heritage and hence need to be considered by IUCN. In order to achieve this, the preamble draws attention to (1) the conceptual framework set by the World Heritage Convention in 1982, which considers geological heritage as part of the natural heritage, (2) the objectives of the current International Year of Planet Earth adopted by the UN General Assembly, and (3) the pioneering steps set by the recommendations of the European Council in 2004."

"The preamble also attempts to recall basic concepts regarding geodiversity and geological heritage, and the need to consider these aspects in nature conservation, land management and sustainable use of resources. It is often forgotten that all we know about Earth's evolution, including the evolution of climate, species, habitats and resources, is based on the geological record. Geological heritage includes those most valuable sites with the best record of Earth's evolution."

"Likewise, the diversity of geological and geomorphological features underpins biological, cultural and landscape diversity, and thus needs to be considered as one more value of natural heritage requiring appropriate adaptive management towards an integrated conservation."

"We believe the time is appropriate for IUCN to begin considering geodiversity and geological heritage in forums and congresses. Our focus with this resolution at this fourth World Conservation Congress is to promote actions and initiatives in this direction, with the hope that future work may gradually develop towards recommendations regarding the conservation of geodiversity and geological heritage. The general objective of this motion strictly follows the general objective of IUCN: to promote the conservation and sustainable use of natural heritage for future generations. But, in order to be complete, natural heritage needs to include geological heritage, the natural archive for the memory of the Earth."

The Motion itself states as follows:

"*NOTING that the United Nations General Assembly proclaimed 2008 to be the International Year of Planet Earth, initiated jointly by the International Union of Geological Sciences (IUGS) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) in order to increase awareness of the importance of Earth sciences in achieving sustainable development and promoting local, national, regional and international action*;"
"*AWARE of the rapidly growing interest and commitment of States, NGOs, and communities to save, study and sustainably use their geodiversity and geological heritage*;"

"*RECALLING that geodiversity, understood to include geological and geomorphological diversity, is an important natural factor underpinning biological, cultural and landscape diversity, as well as an important parameter to be considered in the assessment and management of natural areas*;"

"*RECALLING FURTHER that geological heritage constitutes a natural heritage of scientific, cultural, aesthetic, landscape, economic and/or intrinsic values, which needs to be preserved and handed down to future generations*;"

"*NOTING the pioneering experience led by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and other international institutions in promoting the conservation and sustainable use of geological heritage through the development of the Global Geoparks Network (GGN);"*

"*RECOGNIZING the escalating impact of development that is frequently unsustainable upon the world's geodiversity and geological heritage*;"

"*RECOGNIZING FURTHER that in planning such development, the intrinsic values, both material and intangible, of the geodiversity, geoheritage and geological processes present at natural areas are often underestimated or even ignored*;"

"*AWARE that the Global Geopark Network and Global Geosites Program of UNESCO cover less than 1% of the world's land surface and less than 1% of the marine area, and that most of the geological heritage lies in the wider landscape outside protected areas*;"

"*RECALLING that the Preamble to the World Heritage Convention adopted by the UNESCO General Conference recognizes that the deterioration or disappearance of any item of the natural heritage constitutes a harmful impoverishment of the heritage of all the nations of the world, and that Article 2 considers geological and physiographical formations of outstanding universal value from the point of view of science or conservation as natural heritage*;"

"*RECALLING ALSO the pioneering trend set by the adoption of Rec(2004)3 (Conservation of the Geological Heritage and Areas of Special Geological Interest) by the Council of Europe in 2004, and its call to strengthen cooperation amongst international organizations, scientific institutions and NGOs in the field of geological heritage conservation, and participate in geological conservation programmes*;"

"*RECOGNIZING that the conservation of geodiversity and geological heritage contributes to deal with species loss and ecosystem integrity;*

NOTING that the IUCN guidelines for applying protected area management categories explicitly consider amongst the objectives common to all protected areas the need to: a) maintain diversity of landscape or habitat, b) conserve significant landscape features, geomorphology and geology, and c) conserve natural and scenic areas of national and international significance for cultural, spiritual and scientific purposes;"

"*RECALLING that the conservation of geodiversity and geological heritage at international, national and local levels contributes to the objectives of the United Nations Decade of Education for Sustainable Development (2005–2014)*;"

"*RECOGNIZING the important role of geological and geomorphological conservation in maintaining the character of many landscapes*;"

"*RECOGNIZING ALSO that the conservation and management of geological heritage need to be integrated by governments in their national goals and programmes*;"

"*NOTING that some areas with geological and geomorphological values will deteriorate if they are not taken into account in planning and development policies; and*

AWARE of the need to promote the conservation and appropriate management of the world's geological heritage, in particular areas of special geological interest;"

"*REQUESTS the Director General to: a. Convene a continuing series of meetings on Geodiversity and Geological Heritage in the regions in partnership with members and other organizations; and b. Establish a Secretariat focal point to facilitate the organization of these meetings and to provide their continuity while maintaining the minimum organization and administration possible; and*

"CALLS ON IUCN's Commissions, especially the World Commission on Protected Areas, to support the Secretariat in the design, organization, hosting and funding of future Forum sessions on Geodiversity and Geological Heritage to ensure that this mechanism will achieve the widest possible involvement of government,

independent sector groups, and international organizations around the world."

5.5 The Earth Science Conservation Classification (ESCC)

When considering the management of geological sites it is useful to classify them not only according to their scientific interest (or GCR category), but also to the general character and context. The Nature Conservancy Council devised such a classification in 1990 - the Earth Science Conservation Classification or ESCC- which can still be used as a useful guide to site management, with only the minor addition of a category for '*Mineral and thermal springs'*. This classification is based on two contrasting types of site – '*exposure'* and '*integrity'* - which require a broadly different conservation approach, as described below. English Nature adopted a modified version of this scheme in 2004, by reclassifying some *Integrity* sites as '*Finite'* by retaining only geomorphological sites in the former category and placing all limited deposit sites in the latter. In practice, however, the general principles established by the NCC remain valid. The original and simpler scheme is therefore retained here. The new categories created by English Nature are included in the table below, however, to facilitate cross-reference with the original NCC scheme.

Exposure Sites: These are sites whose scientific or educational value lies in providing exposures of a deposit which is extensive or plentiful underground but which is otherwise accessible only by remote sampling. Typically the deposit or structure in question is widespread underground and is almost certain to contain similar features elsewhere to those visible at the site in question. In practical and economic terms, however, the deposit is not available for study elsewhere due to the logistics and cost of providing an alternative exposure. Exposure sites are generally the most common category of sites and include most quarries, cuttings and coastal outcrops. The primary aim of conservation at such sites is to maintain a representative exposure of the deposit, in a context in which it can continue to be used for research and education. Typical techniques include re-excavation following exposures being obscured by vegetation or talus. Naturally eroding coastlines are consequently, therefore, some of the most important exposure sites, although active quarries can be very important in inland areas. It is also possible to create exposure sites where none existed before.

Integrity Sites: These are sites whose scientific or educational value lies in the fact that they contain finite and limited deposits or

landforms that are irreplaceable if destroyed. Examples include glacial, periglacial, fluvial and coastal landforms and their associated deposits, cave and karst sites, and unique mineral, fossil, or other geological deposits and features. 'Integrity' sites are, by definition, finite and irreplaceable. The primary aim of conservation at such sites is, therefore, to maintain the integrity of the deposit or feature by minimising any changes and controlling any operations that might lead to any net loss or damage.

The Earth Science Conservation Classification (ESCC)	
CATEGORY OF SITE	TYPE OF SITE
Exposure Sites	• Disused quarries, pits and cuttings (includes 'Disused Quarries and Pits' and 'Road, rail and canal cuttings' in EN 2004 scheme) • Active quarries, pits and cuttings (Active quarries and pits in EN 2004 scheme) • Coastal and river cliffs (partly included in 'Coastal cliffs and foreshore' and partly in 'River and stream sections' in EN 2004 scheme) • Foreshore exposures (included in 'Coastal cliffs and foreshore' in EN 2004 scheme) • Mines and tunnels ('Exposure underground mines and tunnels' in EN 2004 scheme) • Inland outcrops and stream sections (includes 'River and stream sections', part, and 'Inland outcrops' in EN 2004 scheme)
Integrity Sites	• Static (fossil) geomorphological sites (includes 'Static (fossil) geomorphological', 'Extensive buried interest' (part) and 'Finite buried interest' in EN 2004 scheme) • Active process geomorphological sites (= 'Active geomorphological sites' in EN 2004 scheme) • Caves and karst (includes 'Caves' and 'Karst' in EN 2004 scheme) • Unique mineral, fossil or other geological sites (includes 'Finite mineral, fossil or other geological' and 'Finite underground mines and tunnels' in EN 2004 scheme) • Mine dumps ('Mine dumps' as a finite category in EN 2004 scheme) • Mineral and thermal springs (category informally adopted following international liaison – not in NCC or EN lists)

A third category of geological heritage is becoming increasingly relevant, however, and is often described as **Moveable geological heritage** *(or "Movable Natural Values")*. This category includes all e*x situ* geological heritage, such as specimens in museums and other collections and becomes highly relevant to site conservation where the locality includes collectable minerals and fossils. Under such circumstances, the needs of geological heritage conservation can be achieved by ensuring that significant specimens removed from the site as part of research or educational activity are deposited in an appropriate museum or other nationally recognised collection. Ironically, for some integrity sites at high risk of damage (such as the gold-bearing veins at Hope's Nose in Torbay that have been subject to illegal collection) conservation in an institution may be the only secure option.

6. Threats and opportunities at geological and geomorphological sites

6.1 Threats, losses and management solutions

Geological sites are extensively threatened in two main ways: firstly by natural degradation, such as the encroachment of scrub which obscures geological exposures and secondly by human pressure, particularly as a result of new development. Within 'exposure sites' it is seldom the geological resource itself which is threatened given the underground extent of most rocks and minerals, but instead the availability of rock faces or outcrops which provide the opportunity for geological study or research. In contrast, the unique or finite nature of 'integrity sites' can mean that a threat to these might result in a permanent and irreversible loss to an element of our Earth heritage resource.

It is not possible to accurately quantify past losses of Earth heritage sites in Devon, but the limited information which is available suggests that the general trends are similar in the County to those experienced in other counties. At a national level in the 1990s, English Nature reported that applications for development or substantial change were received for over 15% of all geological Sites of Special Scientific Interest each year with a significant proportion of these proposals being likely to result in a significant deterioration or damage to the sites if permitted. The overall level of site loss, including non-SSSIs) is probably much higher, however, and although no figures are currently available for Devon, a survey carried out by the former Nature Conservancy Council in Berkshire and part of Surrey demonstrated that of all geological sites

previously recorded in published literature only 18% and 30% respectively still survived in 1975, with further losses to the remaining sites occurring after this time.

Threats to the integrity of Earth heritage site were also reviewed in the 1990 Nature Conservancy Council Strategy, together with a review of the main management solutions to address such problems. The classification presented in the original document remains a very useful framework and is used below with minor modification and brief explanation. English Nature also produced a review of geoconservation case histories in 2006 with included management guidance (see Appendix ix for details). Note that the solutions listed below are not intended to be an inclusive review, other management approaches may be appropriate depending on site-specific conditions.

- **Natural degradation and vegetation growth:** Affects most lowland and inland sites in a temperate, wet climate regime which can become concealed or even inaccessible as a consequence of vegetation growth (including the development of scrub and the growth of lichens). In addition, certain exposures, in particular of mudrocks and soft Quaternary deposits can become chemically and physically weathered, thereby losing some of their original physical and chemical characteristics. In many cases the latter can be associated with either the development of scree and talus or even collapse, in the case of poorly on non-cemented sediments. The surface weathering of some limestones, such as those of Devonian age in Devon can, however, can also lead to surface etching and an enhancement of the visibility of internal features such as fossil corals. *Solutions*: Controlling vegetation growth and removal of scree and talus through the use of hand tools or mechanical excavators. Vegetation can also be controlled with non-persistent herbicides, such as glyphosate. Clearance of limestone exposures should be undertaken with great care, however, so as to minimise damage to delicate features etched out by weathering.

- **Coastal protection and flood defence:** Coastlines with relatively 'soft' rocks such as those in East Devon are most at risk from loss of exposures or damage to landforms and natural processes by the construction of coastal defence works to prevent erosion. Elsewhere, however, Quaternary deposits may also be at particular risk for the same reasons. *Solutions*: 'Soft engineering' provides many alternatives to 'traditional' 'hard' coastal defences, such as beach nourishment, and the use of groynes and off-shore berms.

- **Waste disposal (landfill and effluent):** The disposal of waste materials, including domestic waste and construction materials, is a major problem for many Earth heritage sites, including where illegal tipping is prevalent. Such tipping can bury scientifically important exposures, or inhibit access to them. It can also create significant health and safety issues, and consequently render sites unusable for educational group work. The disposal of liquid effluent or contaminated water can similarly create major health and safety issues, in particular to cave systems, where underground karstic drainage systems can channel discharges into accessible passages and chambers. As well as producing noxious gasses and toxic liquids, such discharges can destroy sensitive cave ecosystems and chemically alter or degrade cave formations and deposits, hence affecting their scientific value as well. *Solutions*: Ensure that active landfill sites do not damage or cover key geological exposures or features, including through the construction of bunds to retain access or by the provision of alternative sites (e.g. by excavation or clearance of former exposures outwith the disposal area). Control fly tipping including by placing barriers to prevent vehicular access to sites.

- **Mineral / aggregate extraction and restoration of working sites:** In densely vegetated lowland Britain, active quarries frequently provide the only 'fresh' exposures of an otherwise concealed geological resource – under certain circumstances, however, the working of such sites can also be a major threat, where relatively small scale deposits and features are at risk from complete or partial removal (i.e. 'integrity' features). In addition, inappropriate restoration and landscaping schemes, post cessation of working, can cover exposures or make access difficult or impossible. *Solutions*: Ensure that working and restoration schemes provide safe and accessible exposures and minimise damage to integrity features. The use of planning conditions is appropriate, especially where the features present are of GCR or RIGS importance.

- **Civil engineering, industrial and domestic developments and projects:** Development is a major threat to many Earth heritage features including both geological sites and geomorphological features. Loss or damage can be a result of direct burial of exposures, effective sterilisation by removing potential access to buried deposits, partial or complete removal of features and by changing natural systems such as by canalising rivers and streams. *Solutions*: Modern planning systems and development planning can minimise the risk of future damage by development to geological and

geomorphological sites – including through appropriate impact assessment procedures.

- **Forestry:** Loss of or damage to geological exposures or landforms by forestry operations is mainly an issue in upland areas, where the use of machinery to prepare the ground and the eventual concealment by growing trees of landforms or damage by their roots can be a major issue. Elsewhere, localised planting or even passive allowance of scrub development can create similar problems. *Solutions*: Maintain non-planting zones around important geological features, ideally a minimum of 5 metres wide to allow mechanical access for clearance works. Ensure that any sites proposed for afforestation are first surveyed to assess their geomorphological significance and minimise any disturbance to such features, e.g. by trenching and forestry road construction.

- **Agricultural and other land management practices:** Agricultural activity includes a number of operations which do not require a formal planning permission under current Town and Country planning legislation. The dumping of agriculturally derived waste materials in disused quarries not subject to statutory protection (e.g. SSSI designation), the construction of certain farm buildings, drainage systems and deep ploughing all have the potential to damage or destroy Earth heritage features. In addition, activities designed to conserve ecological or historical features may also adversely affect earth heritage features if insufficient consultation is carried out. *Solutions*: Agri-environment schemes and an increased awareness of geoconservation issues and opportunities amongst countryside agencies and advisors is crucial to addressing agriculture related issues. Similarly, improved mutual understanding and communication between geological, ecological and cultural heritage management organisations and specialists will not only avoid potential conflicts, it can also present new opportunities. The Devon BAP provides an important framework for establishing such collaboration, as it adopts an integrated ecological and geological approach to natural heritage conservation.

- **Overuse or misuse:** In the UK, large scale site protection issues such as those related to development and waste disposal have been largely addressed through a well developed legislative framework for site protection. One of the most significant remaining threats to a key group of sites where the main geological features are fossils and minerals are third party collecting activities. This '*moveable geological heritage*' lacks direct protection under UK law and in a small number of cases

(such as at Hope's Nose in Torbay) collecting activity has virtually removed key parts of the scientific interest of the site. Elsewhere, although the resource may be more extensive, continued *recreational* collecting of fossils may also not be *sustainable* as the removal of specimens may outpace erosion and as a result a site can lose its some of its educational and scientific value. Other recreational activities can also damage geological sites, such as climbing and caving, especially where features are delicate. *Solutions*: In extreme cases legal powers associated with SSSI or property-ownership legislation can be invoked although in general public awareness campaigns and appropriate signage and Codes of Conduct can be effective. Use of web site searches can be very effective in tracing where illegally removed materials are being traded, and as a first step towards identifying the collector or collectors responsible for damaging the site concerned. For the continued development of geological science, however, it is crucial that geological sites do remain available for the responsible, bone-fide collection of specimens for research and education (see 6.2.3 for further discussion).

A significant threat to many geological sites in the County remains ignorance, however. Although SSSIs are formally notified to landowners, occupiers and planning authorities, a number of Geological Conservation Review sites still remain to be formally notified as part of statutory Sites of Special Scientific Interest (SSSIs - although the great majority of these do lie within existing sites notified for other reasons). In addition, at a few sites the scientific interest lies largely outside of the current SSSI boundary, for instance due to the lateral movement of quarrying operations. In both such cases not only land owners and occupiers but also statutory authorities may be unaware of the importance of the site and inadvertent damage or loss could result. In a related vein, not all RIGS sites selected to date have been notified to owners and occupiers and several local authority areas in the County have not yet commissioned RIGS surveys. Again, ignorance of the status or potential status of those sites of regional or greater scientific importance can lead to inadvertent damage or loss.

6.2 Gains and opportunities for geological conservation in Devon

Although there have been significant losses historically in the County, a number of positive activities in Devon have led to improvements to key sites and hence their increased availability for geological research and education, as well as for interpretation for

the general public. Examples of such gains are recorded in the appropriate Habitat Action Plans in this BAP. Positive activities for geological conservation in the County include:

- Devon RIGS (Regionally Important Geological/Geomorphological Sites) Group promotes geological conservation, by working with local authorities, landowners and others, and provides advice, on request, on County Geological Sites and the management needed to retain or enhance their geological interest. The RIGS Group is undertaking detailed LA by LA surveys - completed projects include for the North Devon AONB, mining districts in West Devon, Torbay, Exeter, South Hams, East Devon, Teignbridge, the Teign Estuary and Dartmoor.

- Devon County Council, the Unitary Authorities and National Park Authorities, as the Mineral Planning Authorities of Devon, implement policies for mineral planning (*e.g.*: those set out in the Devon Minerals Local Plan), which include striking a balance between the demand for mineral resources and the need to protect the environment, having regard to the need for sustainable development, and to ensure the satisfactory after-use of sites after working, with a move away from restoration.

- The British Geological Survey has recently completed new surveys of parts of the County (including Exeter, Plymouth, Sidmouth and Torbay). New geological maps have been published, supported by descriptive memoirs (Exeter, Plymouth) or brief reviews (Torbay, Sidmouth). A new survey of the Tiverton area is currently taking place (2007).

- DCC/EN co-ordinated the Devon Roads and Geology Pilot Project, aimed at identifying opportunities to conserve geological exposures on Devon's road network, and to develop interpretation and education facilities.

- The Devon Educational Register of Geological Sites provides a web-based resource for educational groups and includes over 80 CGSs and SSSIs. Many of these sites are quarries and cuttings.

- An English Nature (now part of Natural England) initiative with the minerals industry fostered awareness and developed partnerships for conservation. A lot of useful publications have resulted.

- The Devon Geodiversity Audit of Active Aggregate Quarries was completed in 2003, providing a resource for developing site use and decision making. The document is also available on CD and

includes detailed descriptions of the main active aggregates quarry sites in the County.

- The Devon Aggregates and Biodiversity Project, a partnership between Aggregates Industries UK and Devon County Council and funded by the Aggregates Levy sustainability fund produced Parish Geodiversity Audits for 10 parishes in the county. These audits not only document the geodiversity present, they also identify opportunities for conservation and community participation.

- Devon County Council and English Nature (now Natural England) have supported the Devon RIGS Group in the establishment of a database of County Geological Sites, including descriptions, maps and photographs. Some of this information is available via the newly established Devon RIGS website.

- The development of the UNESCO-supported Global Geosites initiative provides a context within which the international importance of certain geological and geomorphological features of Devon's pits, quarries and cuttings can be independently demonstrated.

- Torbay has been proposed as a 'European Geopark', a programme supported by UNESCO. 'Coral Coast Geopark' project is supported by Torbay Coast and Countryside Trust, the Torbay Heritage Forum and Torbay Council. Actions to date include the production of new geological interpretation and a Local Geodiversity Action Plan.

- The Dorset and East Devon 'Jurassic Coast' World Heritage Site has implications for sites near the coast of East Devon and a Local Geodiversity Action Plan has been prepared.

- The recently listed Cornwall and West Devon Mining Landscapes World Heritage Site includes a number of quarries and cuttings exposing significant aspects of the County's geology. A geodiversity audit and interpretative review was prepared for the West Devon section of the site prior to submissions. The designation has significant implications for the management of mining-linked geological sites within and adjacent to its boundaries.

- The Meldon Interpretation Project, established by Dartmoor National Park Authority and Devon County Council, has produced a range of interpretative materials, including a guide book, sign boards and web based educational resources to support the

educational and recreational use of one of the county's most important geological area. Previous interpretative projects on Dartmoor include the Burrator Landform Trail and the exhibition '*350 million years in the making*', both relevant to quarry exposures. The materials produced are also available via the Dartmoor National Park Authority's website.

- Local authority projects have led to the clearing and restoration of geological exposures at key CGS sites, most notably in Teignbridge and on Dartmoor. English Nature's 'Facelift' programme has also re-exposed overgrown and degraded sections of several quarry SSSIs in the county.

Specimen collecting is an essential part of the scientific and educational process and the conservation of geological materials, especially fossils and minerals, consequently involves aspects of both site and specimen conservation. In many cases, conservation on-site is not an appropriate option as the natural processes of weathering and erosion and the risk of inappropriate removal make it essential to remove the specimen or specimens to a secure location. Working with county-based museums will ensure that such material remains available for future study and display, including for raising awareness of Devon's rich geological heritage, thereby fulfilling a number of the key functions of such institutions. Crucially, any measures which are adopted to protect sites should not inappropriately restrict geological sampling for scientific or educational purposes, otherwise the site will loose its scientific value and hence a key aspect of its original justification for conservation. Geological heritage conservation can still be achieved by ensuring that scientifically important specimens are deposited in a recognised institution, typically a museum or university – the emphasis simply shifting from site-based to institution-based geoconservation.

7. Natural Areas, Prime Biodiversity Areas and the Regional Nature Map in Devon

7.1 What are Natural Areas?

At first sight the distribution of wildlife and geology across the County and the seas around it may appear very complex, but closer examination reveals some distinctive broad-scale patterns. English Nature used such patterns in the mid 1990s as the basis for the identification of discrete areas with a distinctive combination of geology and habitats. These 'Natural Areas' are not constrained by administrative boundaries, and as such offer a more effective

framework for the planning and achievement of nature conservation objectives than do local authority areas.

Wildlife and geology are not restricted to designated or protected sites such as nature reserves or SSSIs: they occur throughout the countryside, coast and even in built-up areas. No part of England or Devon is without some wildlife interest. Natural Areas allow us to consider wildlife and geological features across whole tracts of the landscape in an integrated way, and have been recognised to be a powerful tool for planning co-ordinated and effective conservation.

English Nature worked closely with the Countryside Agency (with which it is now merged in Natural England) in drawing up its Natural Area boundaries. In Devon they are coincident with the Countryside Character Areas identified by the Agency, with the exception of Lundy which is identified as a separate Character Area. Although the use of Natural Area areas has been to some extent marginalised by the BAP process in England, they still offer a very valuable framework for wider countryside conservation programmes and consequently deserve to be much more widely used.

7.2 Devon's Natural Areas

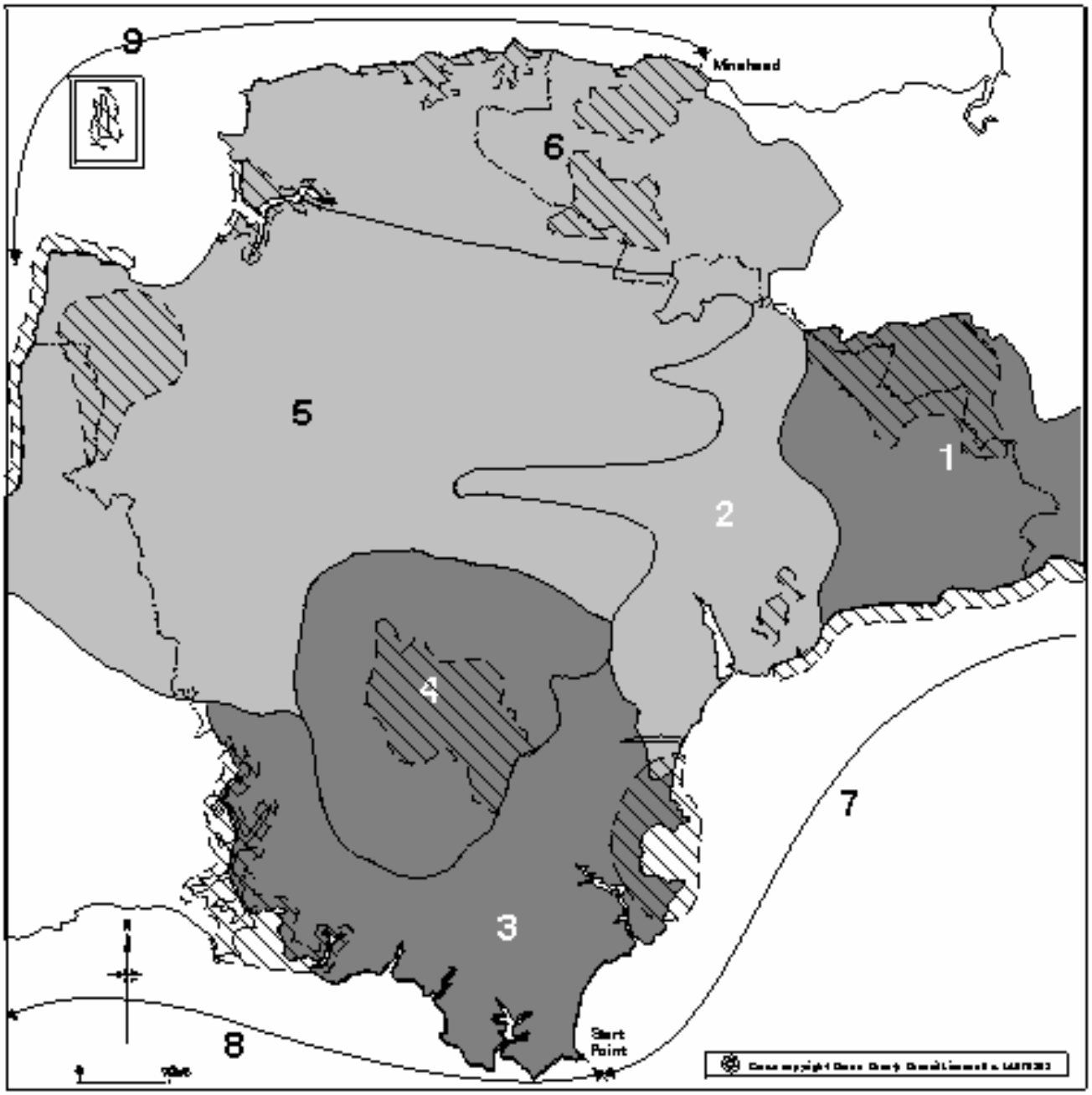
Of the 120 Natural Areas that together make up the entire land surface of England and its sea, nine are present wholly or partly in Devon, as shown in Plan 2. These include three maritime Natural Areas, covering coasts and marine areas. The maritime Natural Areas overlap with adjoining terrestrial ones, each covering the coastal strip. A summary of each of these nine Natural Areas in given below. Full descriptions, known as 'profiles', complete with conservation objectives, are available from Natural England.

Exmoor and the Quantocks - This Natural Area lies very roughly between the Bristol Channel and the North Devon Link Road, and includes the coast from Barnstaple to Minehead as well as Exmoor National Park. The Quantock Hills in Somerset form an outlying area. The dominant geology throughout this area are sandstones and slates of Devonian age with some minor early Carboniferous sedimentary rocks. The Natural Area is of considerable importance for its geology, especially for dramatic exposures of folded Devonian rocks along the coast and with key fossil assemblages including shelly faunas and plants. The most important wildlife habitats present are upland and maritime heaths, western oakwoods, medieval parklands and the outstanding dune system at Braunton Burrows. The heaths are of particular importance for merlin and heath and high brown fritillary butterflies, the woods for rare

endemic whitebeams, the parklands for lichens, and Braunton Burrows for a range of rare plants like water germander. Other important habitats present include rivers, hedges, Rhôs pastures and sea cliffs, the last with colonies of breeding auks.

Blackdowns - The landscape of this Natural Area is strongly determined by its Jurassic and Cretaceous geology which is of outstanding importance for research. The spectacular coastal cliffs capped by Cretaceous Upper Greensand and Chalk with Triassic and Jurassic mudrocks below are of particular note, and yield rich invertebrate and vertebrate faunas of international importance. They also include some of the largest coastal landslip systems in Europe. Mixed livestock farming has produced a stereotypically English landscape of small fields and species-rich hedgerows over the valley slopes and bottoms, while the plateaux have a post enclosure land-use pattern, with large, regular fields. Important heaths occur on the ridges, while spring lines give rise to boggy woodlands, mires and Rhôs pastures. Small streams and rivers contribute to the biodiversity of the landscape. The Natural Area is a major stronghold for dormice, with marsh fritillary butterfly, Bechstein's bat and spring snowflake being other key species.

PLAN 2 : NATURAL AREAS AND PRIME BIODIVERSITY AREAS



KEY

Natural Areas:

1 - Blackdowns
2 - Devon Redlands
3 - South Devon
4 - Dartmoor
5 - The Culm
6 - Exmoor and The Quantocks

Maritime Natural Areas:

7 - Lyme Bay
8 - Start Point to Land's End
9 - Land's End to Minehead

Prime Biodiversity Areas

County Boundary

Devon Redlands - This Natural Area is characterised by the famous Devon-red soils that are derived from the belt of Permian and Triassic sandstones and mudrocks that runs in a broad fertile belt south from Exmoor along the Exe valley towards the outskirts of Torbay. The area includes sites of considerable geological importance, including the Permian volcanic lavas of the Crediton 'trough' andexposures of the famous Triassic Budleigh Salterton Pebble Beds in the east of the area. The majority of the Natural Area is covered by intensive farmland, although a rich network of hedges remains. These, together with numerous small woodlands and river valley habitats ensure the survival of much wildlife interest, including the only populations of white-clawed crayfish in the county. The Natural Area supports the largest extent of lowland heath in Devon, on the pebblebeds of East Devon, the Haldon ridge and in the Bovey Basin: this heathland supports important populations of nightjars, Dartford warblers, birds of prey and southern damselflies. The Bovey Basin also has numerous lakes and ponds associated with the ball clay workings, and these support important assemblages of damselflies and dragonflies. The Exe estuary is of international importance for its bird life, and the sand dunes of Dawlish Warren support the only British population of the sand crocus.

South Devon - This Natural Area runs eastwards from the Tamar across Plymouth and the South Hams to Torbay, skirting the southern edge of Dartmoor. It is characterised by an undulating landscape of rolling hills dissected by numerous river valleys. The area is the premier British holiday venue, the other main land-use being arable and livestock farming. Geologically it is of outstanding importance, and includes many of the sites which formed the inspiration for the Devonian Period in the early part of the 19th Century. Slates dominate, and are associated with sandstones, volcanic rocks and limestones (the latter including karstic features such as caves), the latter in particular being famous for their rich shelly and coralline faunas. The Natural Area has a rich diversity of habitats, including estuaries and caves with species of international importance and sea cliffs, species-rich grasslands and the freshwater lake at Slapton Ley of national importance. A great many rarities have significant populations, among them the cirl bunting, greater horseshoe bat, triangular club-rush, heath lobelia, Plymouth pear and small restharrow.

Dartmoor - The distinctive character of this well known Natural Area is a product of its granite core, the largest in England. Geologically Dartmoor is the largest expanse of unglaciated upland in Britain, and is consequently of considerable geomorphological

importance for its periglacial features, as well as being geologically important for the granite itself and its associated mineralisation. Former mines, quarries and tin streaming works are now a fundamental part of the Dartmoor landscape. Now the main land uses are hill livestock farming, tourism and recreation, military training, forestry, china clay extraction and water supply. The Natural Area contains the largest area of moorland in the south of England, and is of international importance for its blanket bogs, upland heaths and upland oakwoods, and of at least national importance for its valley mires, Rhôs pasture and grass moor. Key species present include golden plover, fritillary butterflies, blue ground beetle and various very rare lichens.

The Culm - Occupying the broad tract of land between Exmoor and Dartmoor, the 'Culm' is characterised by low rolling hills covered by small irregular pasture fields divided by hedgebanks. Its name is derived from the underlying geology of Carboniferous slates, shales and sandstones which were formally known as the 'Culm Measures': these rocks generally give rise to heavy acidic clay soils. Three major rivers cut through the area, the Taw, Torridge and Tamar. The main land use is livestock farming which, together with forestry, ball clay extraction and tourism, provides the economic mainstay for the population. The area is of outstanding importance for geology, particularly along the high coastal cliffs where key rock strata and landform features are dramatically displayed, but also for minerals and quarry exposures. The Natural Area contains one of the greatest concentrations of species-rich grasslands remaining in the UK: the grasslands in question are known as Culm grasslands. This habitat, along with the ancient oak woodlands along the coast, parkland and sea cliffs, is all of international importance for nature conservation. Other notable habitats include the hedgebanks, wet woodlands, rivers and streams. The Natural Area is of particular importance for otters, barn owls, marsh fritillary butterflies, freshwater pearl mussels and rare lichens.

Lyme Bay - This maritime Natural Area takes in the Great West Bay between Start Point and Portland Bill, and the coastal fringe. Geologically, the area is of outstanding importance with the coastal cliffs having many key localities for the study of Devonian, Permian, Triassic, Jurassic and Cretaceous strata. These rocks locally yield rich fossil faunas, including evidence of tropical reef systems in the Devonian rocks of south-western areas and Jurassic ammonites and marine reptiles to the east. The landslips at the Undercliffs near Lyme Regis are also exceptional. Biologically, it is an area of change, straddling the divide between the warm waters of the south west and the colder waters of the North Sea and eastern Channel. As such, unusual marine species such as the pink sea fan, rose coral

and southern sunset cup coral can be found on the important undersea reefs. Dolphins and basking sharks are frequent. The key wildlife habitats present are these reefs, estuaries (particularly the Exe Estuary which is of international importance for its birdlife), coastal lagoons and their associated shingle banks (at Chesil and Slapton), and soft eroding cliffs of European importance for sea cliff vegetation. These habitats are important for many species including avocets, brent geese, eel grass beds, the early gentian and numerous invertebrates.

Start Point to Land's End - Like the Land's End to Minehead Natural Area, this Natural Area is a prime destination for tourists, but in contrast its landscape is gently rolling and soft, with many sheltered coves. It is characterised by a succession of estuaries developed within drowned river valleys and known as rias. The highly indented nature of these rias means that the Natural Area covers a staggering 720 km of coastline. Geologically, the Natural Area is again of outstanding importance, including for the metamorphic schists of the Start Complex in the east and Devonian sedimentary rocks from Plymouth south-eastwards. Features related to changes in sea level such as raised beaches and rias record sea level changes over the last few 100s of 1000s of years. Biologically, the open sea is important for whales and dolphins, turtles, basking sharks, gannets, divers, skuas and grebes. Rocky areas of sea bed and sea shore support sea fans, cup corals, and unusual kelps, among many other special species. Muddy, sandy or gravel areas are also important, hosting rarities like sea pens and Stephen's goby, as well as large eelgrass beds. The Tamar estuary which straddles the border between Devon and Cornwall is of international importance for wetland birds such as avocets and black-tailed godwits (and increasing numbers of little egrets), while others such as the Salcombe-Kingsbridge estuary are of great important for marine life. Many of the estuaries are fringed with ancient oak woodland rich in lichens and mosses. The cliffs and headlands in-between support important rock crevice communities as well as fine maritime grassland and heathland with many rare plants, insects and spiders. Adjacent farmland supports significant populations of declining farmland birds including the very rare cirl bunting. Apart from tourism and agriculture, the other main economic activities in the area are fishing, commercial ports and docks, military training and aggregate extraction.

Land's End to Minehead - This is one of the largest maritime Natural Areas in England, stretching along approximately 320 km of coastline along the north coasts of Cornwall, Devon and west Somerset. Being generally wild and rugged in character, the area is important for tourism and recreation in all three counties. Other

main economic activities include fishing, aggregate extraction and military training, and along the associated coastal strip agriculture. Geologically, the area's extensive and often spectacular coastal exposures are of outstanding importance for the study of geological features such as Variscan folding and Devonian and Carboniferous sediments with associated fossil faunas. Key coastal erosion features including arches, stacks and hanging valleys. In terms of its wildlife, the Natural Area is of international importance for its marine life around Lundy (England's only Marine Nature Reserve), vegetated sea cliffs and sand dune systems (particularly that at Braunton Burrows). Numerous rarities occur including endemics like Lundy cabbage, early gentian and a sub-species or rock sea lavender. Other special species include golden hair lichen, water germander, round-headed club-rush, petalwort (liverwort) and peregrine falcon. The oak woods of the sea cliffs, sometimes bizarrely stunted by extreme exposure, are of great importance for lichen conservation. Out to sea, the area is important for basking sharks, divers, gannets, manx shearwaters, auks (which breed on Lundy's cliffs), dolphins, porpoises and grey seals. The extensive reefs of tide-swept bedrock around Lundy support rare sponges, sea fans and cup corals, while rare sea weeds and sea slugs are to be found in the intertidal area.

7.3 Prime Biodiversity Areas

Rather than targeting conservation effort towards an entire Natural Area, there can be benefit in concentrating effort within a few localities with particular concentrations of special sites or high biological diversity. Such areas might be considered to form 'Prime Biodiversity Areas'. They are areas of maximum opportunity where resources may be targeted most effectively to achieve wildlife conservation. Like Natural Areas, Prime Biodiversity Areas are not a designation, but instead are intended to highlight and to focus conservation attention upon Devon's most important wildlife localities.

A number of Prime Biodiversity Areas are identified in the County's Natural Area profiles.

7.4 Regional Nature Map

The South West Regional Nature Map has recently been developed by Biodiversity South West in liaison with many regional and county experts. This map highlights blocks of land that are important for both the conservation and, crucially, expansion of important habitat

types. These blocks of land are known as Strategic Nature Areas (SNAs). They have been prepared for the following habitat types that are relevant to Devon:

- Woodland
- Limestone grassland
- Neutral grassland
- Purple moor-grass and rush pasture
- Upland heath*
- Lowland heath
- Coastal and floodplain grazing marsh
- Coastal habitats

* habitat without an action plan in the Devon BAP

The Nature Map is part of a new approach to wildlife conservation. Whilst the conservation of individual sites of important wildlife habitat remains as vital as ever, there is an increasing recognition that this traditional approach to conservation is not enough on its own.

The SNAs present an opportunity for landscape-scale conservation. They provide a framework for planning both the conservation and re-creation of semi-natural habitats, thus providing the connectivity within the landscape necessary to enable plants and animals to migrate and establish sustainable populations and communities.

Further details on the Regional Nature Map, including detailed GIS layers that can be downloaded for Devon, can be found on the web site of the South West Observatory.

As well as being a useful tool to land managers and conservationists, the Nature Map should prove to be highly valuable to Local Planning Authorities. It provides a tool for helping to map those areas which might be prioritised for biodiversity enhancement through Local Development Frameworks (LDFs), in accordance with Planning Policy Statement 9.

In order to help planners to visualise the Regional Nature Map within their patch, simple maps showing SNAs for relevant habitats have been produced for all of Devon's district, borough and unitary authorities. They are included within this BAP, along with similar information for Areas of Outstanding Natural Beauty (AONBs). The South West Observatory should be referred to for definitive boundaries.

Please note, however, that many areas of land not shown on the Nature Map also contain significant concentrations of wildlife habitat and opportunities for biodiversity enhancement. These may still represent priority areas which should be recognised through the preparation of LDFs at a district scale.