Biodiversity Audit of the Norfolk Coast

– Phase 1 Report

Liam Crowther, James Gilroy, Dan Salliss,
Rob Hawkes & Paul Dolman




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University of East Anglia

A Biodiversity Audit to support evidence-based nature recovery:

- Funded by a **public-private partnership** of farmers, conservation ngo's, Local Authorities and Natural England, the audit collated **over a million species records**, and worked closely with expert taxonomists and site managers so that nature recovery on the Norfolk Coast can be an exemplar of **evidence-based conservation**
- **10,759 species** have been recorded on the Norfolk coast from 1980.
- at least **1,274 species** are **conservation priorities**.
- The Norfolk coast holds some of the largest and best **saltmarsh** (nearly 3,900 ha), freshwater **grazing marsh** (more than 1,130 ha) and **dune landscapes** (541 ha) in the UK, all are vital to this biodiversity.
- These **Norfolk habitats support as many, or more, priority species than comparable major complexes** elsewhere in England and Wales.
- Sea level rise, climate change and the growing need for managed realignment together pose serious challenges to these habitats and their wildlife.
- To achieve the objectives of protecting, sustaining and expanding this important wildlife, land managers should take a series of important actions identified through this Biodiversity Audit, to benefit numerous neglected groups.
- Current **site management can be further improved**, potentially with support of the sustainable farming incentive and local nature recovery, to better support the full range of important species
- Bold **landscape-scale actions for nature recovery** should be taken to restore, buffer and protect habitats and their wildlife, enhance natural coastal dynamics for flood protection, sequester carbon, recreate threatened habitats and restore a resilient connected landscape to assist species migration and mitigate coastal squeeze.
- Together **this will bring multiple benefits to the full range of wildlife** including neglected groups.

Biodiversity Audit
Nature Recovery
Fine-tuning habitats


Brown-banded carder bee, *Bombus humilis*
© Arnstein Staverløkk

Cover photo credits: Andy Bloomfield, James Gilroy, Danny S, Matt Wilson.

Opportunities for bold landscape-scale nature recovery and habitat creation

To truly recover the full range of **threatened and declining wildlife including neglected groups**, and to **increase resilience** to climate change and sea-level rise, land managers should **expand, buffer** and **improve habitat connectivity** within the study area, by **creating new habitat** and **restoring degraded** areas. Such actions may be supported by local nature recovery and landscape recovery but extend beyond the scope of the sustainable farming incentive.

- Areas currently under **arable** or **intensive pastoral** management within the coastal floodplain should be targeted for **large-scale creation of new low-input grazing marsh** / fen / wetland complexes. This will expand and buffer existing wetlands from future risks (including sea level rise), sequester carbon, and improve visual amenity for millions of visitors to the coast each year. Restoring complex drainage networks will prepare coastal areas for future saltmarsh expansion.
- Some **existing grazing marsh** areas that are at high risk of sea defence failure should be actively **converted to saltmarsh**. Managed realignment can increase the protection given to remaining freshwater wetlands lying behind the realignment. Emerging carbon markets will provide opportunities for financial support.
- Future loss of freshwater habitats in the coastal plain should be compensated for by **creating or enhancing grazing marsh and wetlands along valley floodplains** and also would be offset by gains in saltmarsh biodiversity and ecosystem services.
- **Dynamic natural processes on sand dunes should be restored** by removing conifers and mobilising fixed grey dunes. This will increase the area and resilience of dune habitats and their wildlife. Restoring landward movement can maintain overall depth and coastal defence function, in contrast to fixed immobile dunes that may become vulnerable to erosion at the seaward edge (depending on local sediment transport patterns).
- **Landward arable fields** outside but **adjacent to the coastal floodplain** should be **converted to semi-natural cover (grass-scrub mosaics, chalk grassland, heathland, wood-pasture)**. This will improve **connectivity** between dunes marsh and landward habitats and **enhance and protect water quality** entering the coastal wetlands.

In the last 16 years 357 ha of new grazing marsh has been created through HLS and CS.

However, there remains ≈ 5,000 ha of arable land within the study area to be converted to semi-natural habitats.

Opportunities to further improve current habitat management:

Land managers have achieved important conservation successes, but outcomes for wildlife should be further enhanced by fine-tuning. The biodiversity audit highlighted key habitat features and resources that should be enhanced through interventions (potentially implemented through the Sustainable Farming incentive / Local Nature Recovery schemes) that can differ from current management priorities.

In **grazing marshes**, the audit showed that:

- wet grassland habitats should be managed to give a **full range of habitat structures** across different areas, from **short swards** needed by flagship breeding waders, through to **tall swards** and shrubby areas that are important to priority wildlife but may currently be undervalued
- varied grazing management (intensities, stock types) ensuring a range of sward structure should be delivered across the full spectrum of hydrological conditions.

For **freshwater features**, including **drainage ditches and streams** in both arable and pastoral systems:

- drainage ditch banks should have shallow (not steep) profiles and margins that differ in vegetation height/density as well as areas of bare substrate
- water quality across the region should be quantified, and threats to water quality within the coastal area and surrounding catchments identified.

For sand **dune and shingle** systems:

- encouraging sand mobility and disturbance is necessary to avoid open micro-habitats that are needed by some important wildlife being smothered by dense vegetation, due to increases in nutrient deposition, loss of rabbits, climate change and invasive species

For **saltmarshes**:

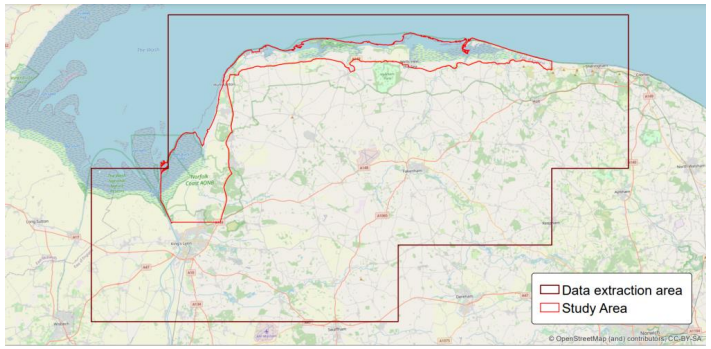
- natural salt marsh habitats should be preserved in an ungrazed state (aside from natural grazing by wildfowl) to protect important specialist flora and invertebrate populations


© Evelyn Simak

Detailed examination of these options, and the biodiversity evidence underpinning them, is presented for each biotope in the subsequent sections of this report (navigated through top-row menu buttons).

Aims of this audit

The iconic landscape of the Norfolk Coast is famed for vast expanses of saltmarsh, sand dune, grazing marshes and wetlands along 105 km of coastline. Most of the coastal and inter-tidal habitats are protected for their nationally and internationally important biodiversity (as SSSI, Ramsar wetland, SAC and SPA)[1]. However, managers have lacked comprehensive information on how to support the full suite of important biodiversity, and even what the full range of species might be.



The dynamic coastal ecosystems are home to a remarkable diversity of wildlife.

Importantly, the success of habitat management for biodiversity depends on how well land managers understand the **needs of all species** in their area. The ecological and management requirements of some groups - particularly birds – are already well-known, and conservationists often assume that management for these species will benefit other more poorly-known groups.

However, the ongoing declines in UK biodiversity at a national level suggest this assumption is **not always delivering wider nature recovery**. This Biodiversity Audit was carried out to fully quantify the scale and requirements of the Norfolk Coast's 'off-radar' biodiversity (plants and invertebrates) to support novel approaches to evidence-based conservation in the area.

This Biodiversity Audit used **over a million biological records** and captured a **wealth of knowledge from regional species experts and managers** to:

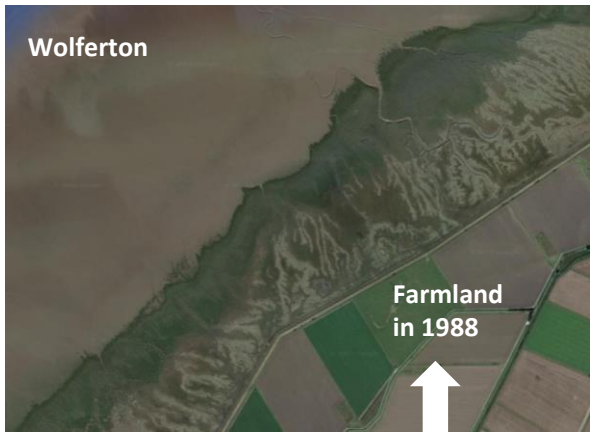
- Collate the first comprehensive list of the many thousands of species found in the region;
- Analyse and synthesise information on the ecological, habitat and management needs of hundreds of priority species (threatened, rare, or localized) across a wide range of taxonomic groups to give a robust and comprehensive understanding;
- Translate this information into clear management guidance so that land managers can best support and enhance the important biodiversity across the fullest range of priority species, to secure this important biodiversity and natural heritage for the future.

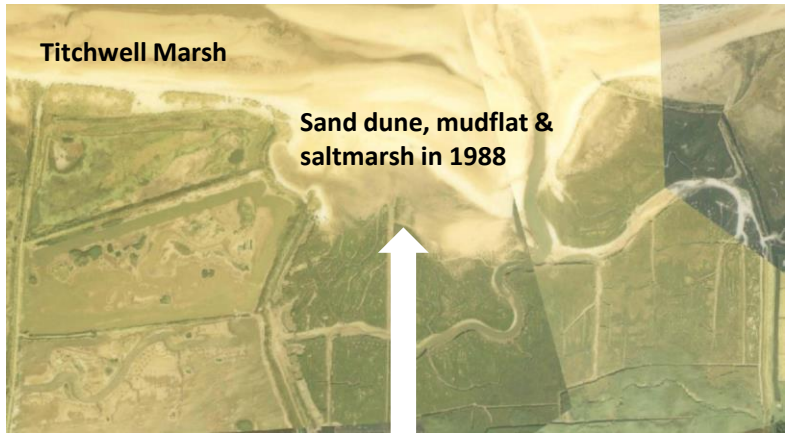
See **Methods** pages for full details of the audit process.

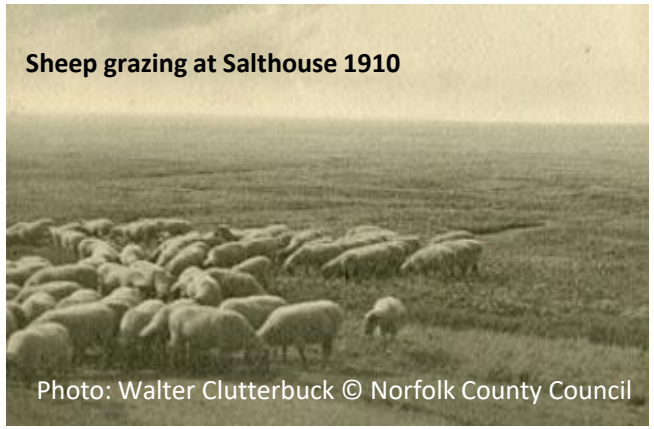
Aims | Challenges & opportunities | How to use this report

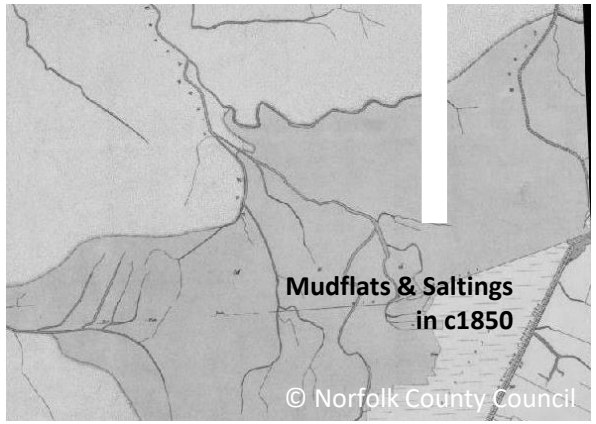
[1] including the North Norfolk Coast SSSI (7,862 ha), a Ramsar Wetland, SAC (designated for Coastal lagoons, Vegetated stony banks; Mediterranean/thermo-Atlantic halophylous scrub within Saltmarsh or shingle; Embryonic shifting, Yellow and Grey dunes; Dune slacks; Otter *Lutra lutra*; Petalwort *Petalophyllum ralfsii*) and SPA (for Bittern *Botaurus stellaris*, Dark-bellied Brent Goose *Branta benicla*; Pink-footed Goose *Anser brachyrnhynchus*; Waterbird assemblage and Wigeon *Anas Penelope;* Avocet *Recurvirostra avosetta*; Knot *Calidris canutus*; Common Tern *Sterna hirundo;* Little Tern *S. albifrons*; Sandwich tern *S. sandvicensis*; Marsh Harrier *Circus aeruginosus*; Montagu's Harrier *C. pygargus*); and contributes to the Wash and North Norfolk Coast SAC (for Marine sandbanks; Mudflats and inter-tidal sandbanks; Coastal lagoons; Inlets and bays; Reefs; Colonising saltmarsh; Salt meadows; Mediterranean/thermo-Atlantic halophylous scrub; Otter; Common Seal *Phoca vitulina*) and Greater Wash SPA (for Common Scoter *Melanitta nigra*; Common tern; Little Tern; Sandwich Tern; Little Gull *Hydrocoloeus minutus*)

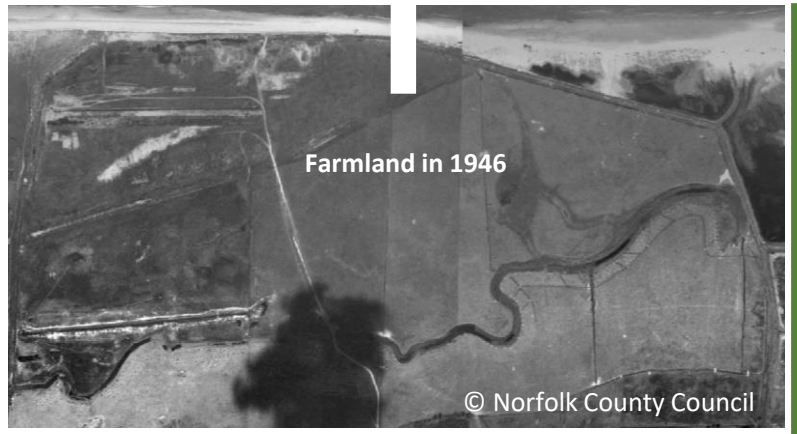
Human history of a dynamic natural coastline











Some dunes & saltmarsh were formerly livestock-grazed. The saltmarshes have not been grazed for over a century except by wintering geese, but conservation grazing is reintroduced to some dunes.

Large areas of inter-tidal saltmarsh were reclaimed by sea walls from the 1700's, creating freshwater grazing marshes, parts of which were then drained for arable. Some freshwater grazing marsh and farmland later returned to saltmarsh, either by storm surges (as at Titchwell above) or by managed restoration. Sea level rise and climate change are increasing the flood risk which is particularly acute on low-lying reclaimed lands.

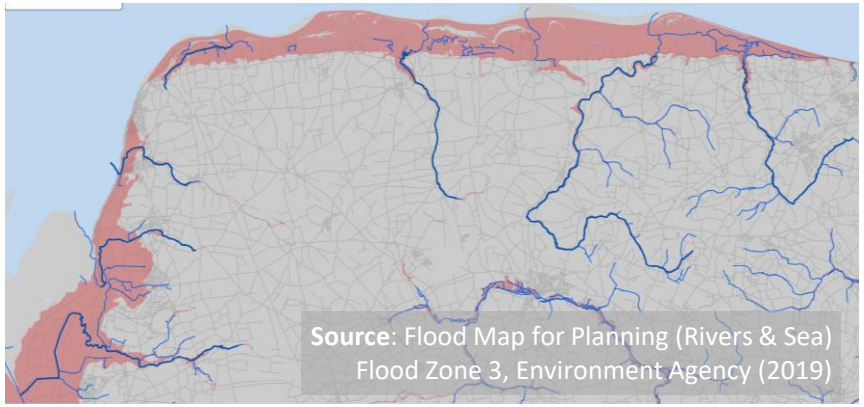
For many centuries the diverse habitats of the Norfolk Coast have been shaped by two powerful forces: **nature** and **people**

Key Aim: Understanding the biodiversity importance of freshwater grazing marshes *relative to* saltmarshes, and whether grazing best supports the biodiversity of coastal habitats, will help ensure resilient management

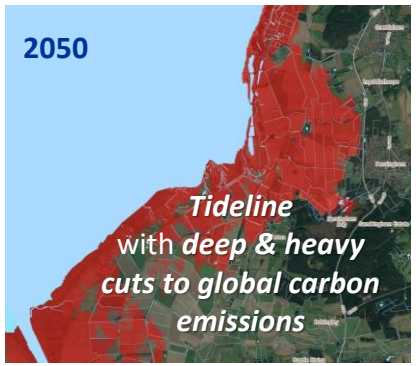
Aims
Challenges & opportunities
How to use this report

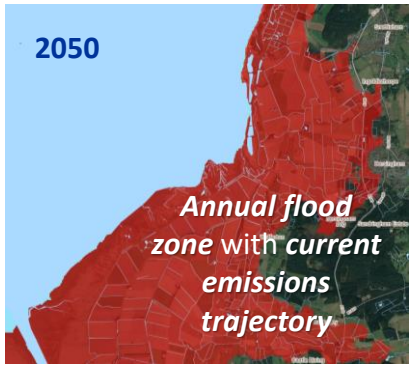
Facing upcoming challenges

Flooding at Salthouse Marshes after a storm surge breached the shingle bank December 2013



Climate change is causing sea levels to rise and storm winds to become more frequent. Coastal flooding, storm surges and over-topping of banks will happen more often and will be more severe, with 10-year storm events on the North Sea coast predicted to be up to 1m higher than present by 2100 [1].





Source: Kulp & Strauss (2019) *Nature Communications* 10(1), 1-12.

The coastal plain is at increasing risk of tidal flooding.

Environment Agency Shoreline Management policy for North Norfolk is to gradually increase natural processes, while providing flood defence 'where technically possible and economically viable.'

Continuing to 'hold-the-line' will protect river outfalls, important settlements and infrastructure. However, some sections will see no further investment in coastal defence (e.g. Thornham-Titchwell, Cley-Salthouse) while managed realignment (passive, or through deliberate breaches) is considered an option in the short- (e.g. Holme dunes, Holkham dunes), medium- (2025-2055: Old Hunstanton dunes, Blakeney freshes) or long-term (2055-2105: policy uncertain at Brancaster, Deepdale, Norton and Overy marshes, Cley marshes) [2].

Existing coastal defences in west Norfolk (Wolferton Creek to South Hunstanton) may become unsustainable, with managed realignment considered for the medium-term [3].

A Key Aim of this study
is to quantify the relative biodiversity importance of grazing marsh wetland complexes and saltmarshes to inform decisions on holding the line or managed realignment.

Aims
Challenges & opportunities
How to use this report

[1] Based on RCP4.5 scenarios from Muis et al. (2020) Frontiers in Marine Science 7, 263.
[2] Environment Agency (2010) North Norfolk Shoreline Management Plan: Final Plan Nov 2010 EACG (East Anglian Coastal Group) - SMP 6
[3] Environment Agency (2010) The Wash Shoreline Management Plan 2: Gibraltar Point to Old Hunstanton, August 2010 http://eacg.org.uk/smp4.asp

Novel opportunities for nature recovery

Policy paper

Environmental land management schemes: outcomes

Published 6 January 2022

Defra Environmental Land Management Schemes (ELMS) will replace earlier agri-environment and Basic Payment Schemes. ELMS will pay for public goods including improved water quality, biodiversity, natural flood management, and mitigation of coastal erosion risk. Within ELMS:

Sustainable Farming Incentive agreements will pay farmers to make agriculture more sustainable and to enhance biodiversity.

Local Nature Recovery is an ambitious replacement for Countryside Stewardship, paying for locally-appropriate actions and local collaborations to support habitat creation and restoration and natural flood management.

Landscape Recovery will pay landowners for more radical and large-scale land use change and habitat and ecosystem restoration, supporting environmental and climate outcomes

Environment Act 2021

2021 CHAPTER 30

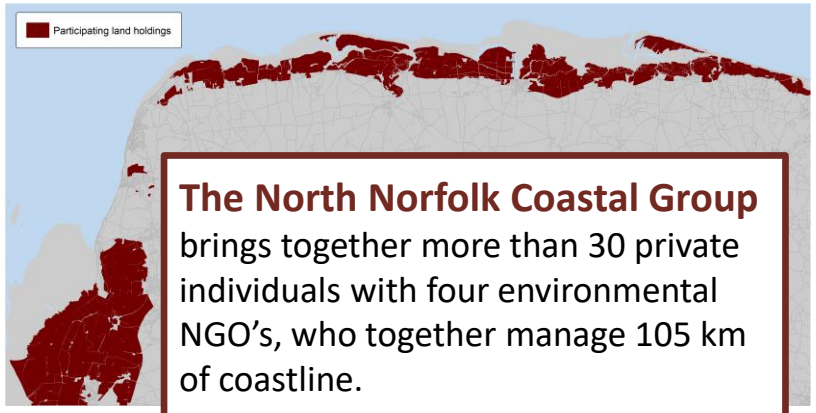
The Environment Act 2021 requires responsible authorities across England to prepare **Local Nature Recovery strategies (LNRS)**.

These should define regional landscape-scale biodiversity priorities, opportunities and priorities for biodiversity recovery or enhancement, and potential measures to achieve these.

This Biodiversity Audit provides a comprehensive, robust and objective assessment of priority biodiversity from which to develop such a strategy.

The Environment Act 2021 **Biodiversity gain in planning** should lead to opportunities to register **biodiversity gain sites** and **trade biodiversity credits.**

Emerging Carbon Markets currently offer financial incentives for woodland creation, and new 'blue carbon' markets may soon offer similar incentives for saltmarsh creation. A UK **Saltmarsh Code for carbon finance** is currently under development, and is expected to operate in a similar fashion to the current Peatland and Woodland Codes, providing finance for habitat creation schemes.



The North Norfolk Coastal Group brings together more than 30 private individuals with four environmental NGO's, who together manage 105 km of coastline.

This cooperation can allow members **to lead transformative change**, through a shared vision designed to enhance biodiversity resilience at a landscape scale.

Aims | Challenges & opportunities | How to use this report

How to use this report: Understanding our three main biodiversity metrics

Throughout this report we use three key metrics to quantify the importance of habitats and their constituent features for biodiversity. These metrics are derived from comprehensive analyses of the **plant and invertebrate species** associated with each different habitat, classified into specific management guilds. Below are brief explanations off how each metric is calculated, with full details in the Methods section.

1) % of Possible Species:

This is the **percentage** of *all English invertebrate* species **requiring a given habitat feature** that have been recorded in study area. Higher percentages indicate that the study area supports good examples of a given feature in a national context

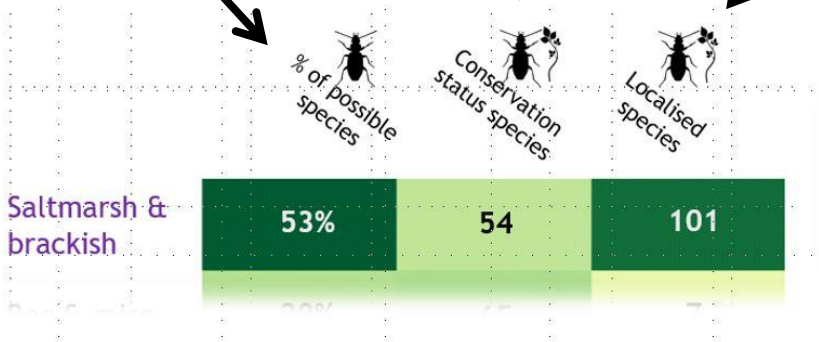
2) Conservation status species:

Numbers of IUCN threatened, Nationally rare or scarce, S41 or RDB

3) Localised species:

Numbers of species for which **our area is vital** (>10% British range)

e.g. *Marpissa nivoyi* NS spider of sparsely vegetated dunes: 5 of 19 hectads = **26.3% of British range**



Useful definitions:

Biotope: a collection of similar habitats that are subject to the same processes (e.g. freshwater wetlands). **Habitat:** A component of a biotope (e.g. standing water). **Management guild:** The species associated with the microhabitats created when a habitat is managed in a certain way (e.g. densely vegetated pool margins). See Glossary (page 45) for more.

Species were assigned to habitats and management guilds[1] , for invertebrates using the Pantheon database[2], for plants using guilding information from previous Biodiversity Audits, backed up by ecological information from the Online Atlas of the British and Irish Flora.

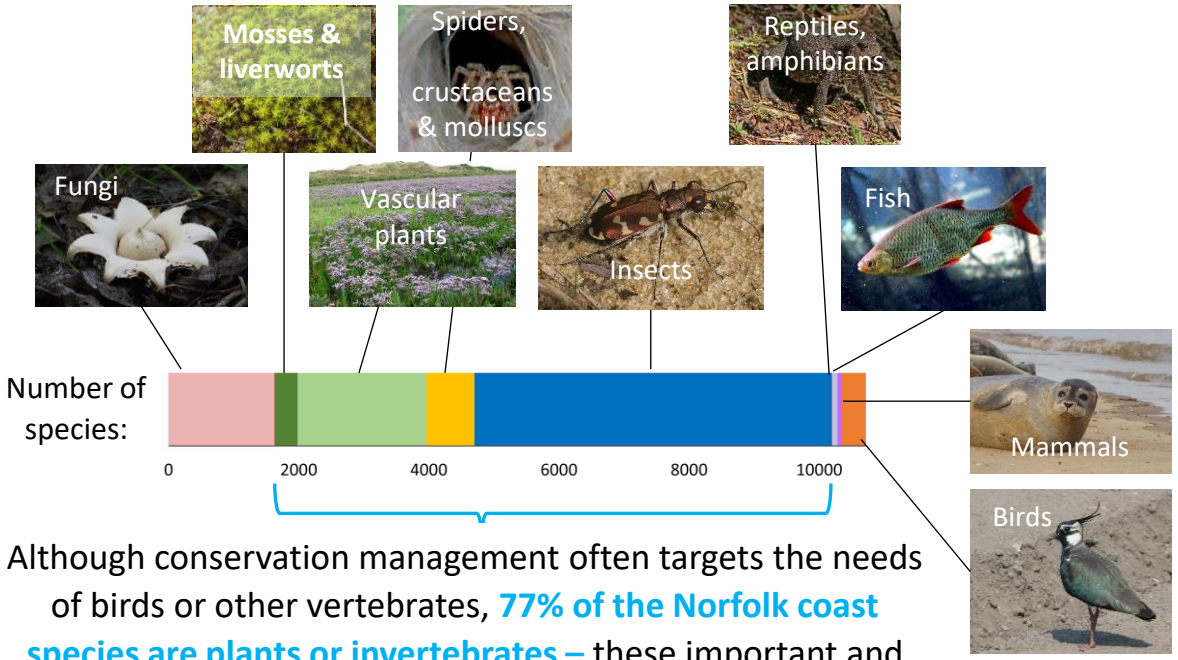
Aims
Challenges & opportunities
How to use this report

[1] Dolman, P.M., Panter, C.J., Mossman, H.L. (2012) The biodiversity audit approach challenges regional priorities and identifies a mismatch in conservation. *Journal of Applied Ecology* **49**, 986–997.

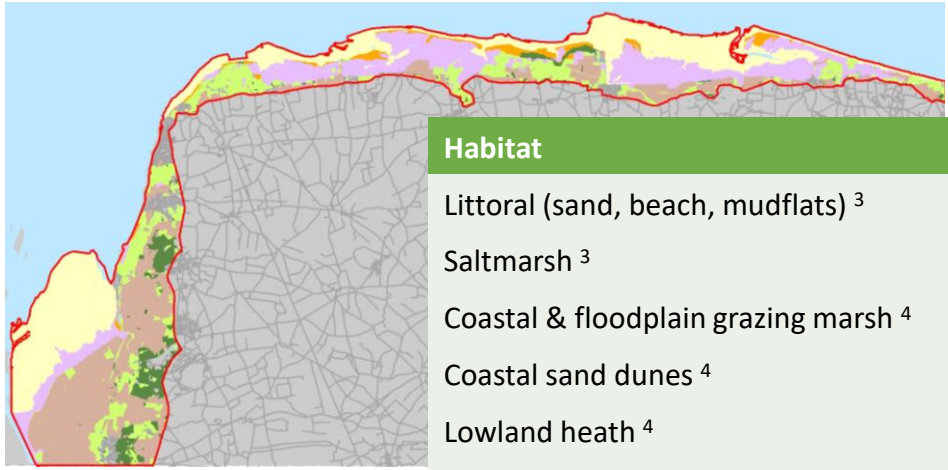
[2] Webb, J., Heaver, D., Lott, D., Dean, H.J., van Breda, J., Curson, J., Harvey, M.C., Gurney, M., Roy, D.B., van Breda, A., Drake, M., Alexander, K.N.A. and Foster, G. (2017). *Pantheon - database version **3.7.6***. [online] Available at: **http://www.brc.ac.uk/pantheon/** 2: 3:

Key findings: The major habitats of the Norfolk Coast together support nearly 11,000 species

- **10,759 species have been recorded** on the Norfolk coast from 1980
- of these at least **1,274 should be considered a high priority for conservation**, including:
  - **755 with a conservation status** [1]
  - **592 that are nationally localised**



Although conservation management often targets the needs of birds or other vertebrates, **77% of the Norfolk coast species are plants or invertebrates –** these important and widely declining groups are the core focus of this audit.



Findings across biotopes

Habitat	Area (ha)
Littoral (sand, beach, mudflats) [3]	6,386
Saltmarsh [3]	3,887
Coastal & floodplain grazing marsh [4]	1,131
Coastal sand dunes [4]	541
Lowland heath [4]	106
Conifer [3]	423
Arable [3]	5,334
Urban [3]	140
other	*2,851*
Total Study Area	**20,798**

The Norfolk coast holds some of the largest and best **saltmarsh** (≈ 3,900 ha), freshwater **grazing marsh** (>1,130 ha) and **dune landscapes** (541 ha) in the UK.

All are vital to this suite of wildlife.

Wildlife delivery and the development of LNRS (see p.8) require **accurate, up-to-date, reliable mapped land-use data**. However, many restored and newly-created grazing marsh areas in the study area were not yet included in NE's Priority Habitats Inventory (mapped above), while the extent of arable mapped by CEH Landcover is also unreliable.

[1] Assessed on JNCC lists as Near-Threatened or at greater risk
[2] with 10% or greater of their national range within the Norfolk Coast study area
[3] mapped from CEH Landcover (LCM 2015), may over-estimate arable area
[4] mapped from NE Priority Habitats inventory, does not include recently created grazing marsh (incl. North Point Marshes; Quarles Marsh; Spook's Marsh & further areas E of Wells; Burnham Deepdale; Burnham Overy (Hancock's Marsh)

Key findings: Each major biotope on the Norfolk Coast supports nationally important biodiversity

The range of natural and human 'biotopes' (habitat complexes) on the Norfolk Coast together support large numbers of priority species.

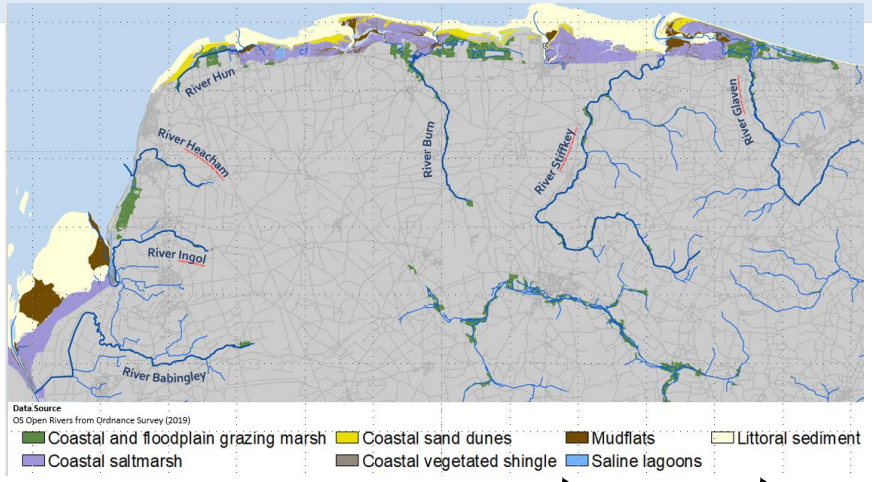
Saltmarsh and brackish habitats have the most representative assemblages, with 53% of the potential suite of invertebrates associated with that biotope nationally, greater than other biotopes found in the study area.

Saltmarsh and brackish habitats also support more localised species for which the Norfolk Coast contributes >10% of their national range, approximately twice the numbers in the **grazing marshes / wetlands** or **dunes, shingle, heath and dry grassland** (see opposite).

Dunes, shingle, heath and dry grassland and **grazing marshes / wetlands** also support a great many species of conservation importance.

Both **grazing marshes / wetlands** and **dunes, shingle, heath and dry grassland** support nearly three-times as many priority species (invertebrates and plants) than **saltmarsh and brackish** habitats (see opposite) but this is unsurprising, as far fewer species can tolerate saline conditions. However, **saltmarsh and brackish** has better representation of a smaller potential national biotope pool of species.

Most species adapted to saltmarshes are not found in other habitats and inevitably have a limited national range, while many species found in coastal dunes and freshwater complexes are also found in various inland habitats, so we expect many to have a wider national range and therefore less likely to be localised to the Norfolk coast.

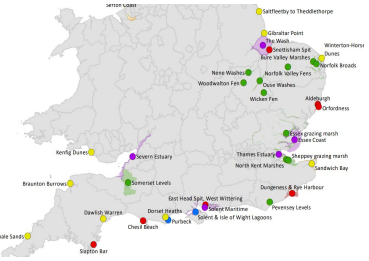


Findings across biotopes

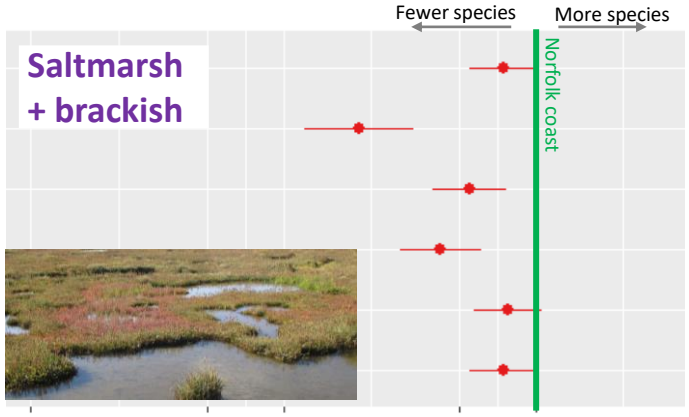
	% of possible species	Conservation status species	Localised species
Saltmarsh & brackish	53%	54	101
Bog & mire	29%	65	7
Grazing marsh & wetland	37%	151	46
Dune, shingle, heath, etc.	40%	143	48

Note that wetland habitats include dune slacks. Bog and mire habitats were not a focus in this study due to their limited area in the focal region, but they have a short summary under 'other features'.

Key findings: The Norfolk Coast supports some of the most important coastal habitats in England and Wales



Essex Coast
Ribble Estuary
Severn Estuary
Solent (lagoons)
Solent (maritime)
Thames Estuary



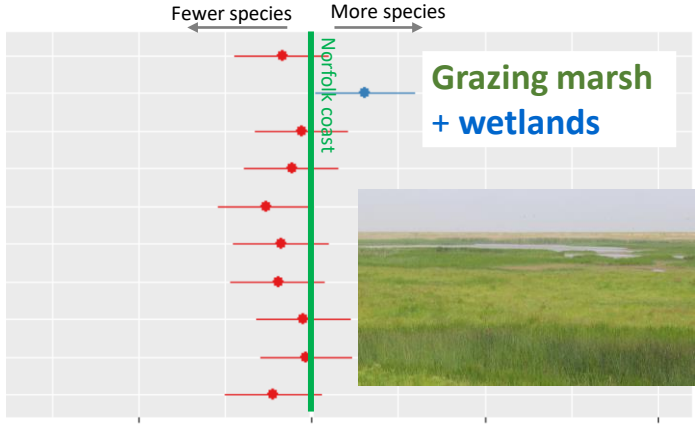
Relative numbers of priority invertebrate species compared to Norfolk Coast (green line)

Braunton Burrows
Dawlish Warren
Gibraltar Point
Kenfig
Saltfleetby
Sandwich Bay
Sefton Coast
Winterton

Relative numbers of priority invertebrate species compared to Norfolk Coast (green line)

Findings across biotopes

Bure Valley
Essex Marshes
Kent Marshes
Nene Washes
Pevensey Levels
Sheppey Marshes
Somerset Levels
Wicken Fen
Woodwalton Fen

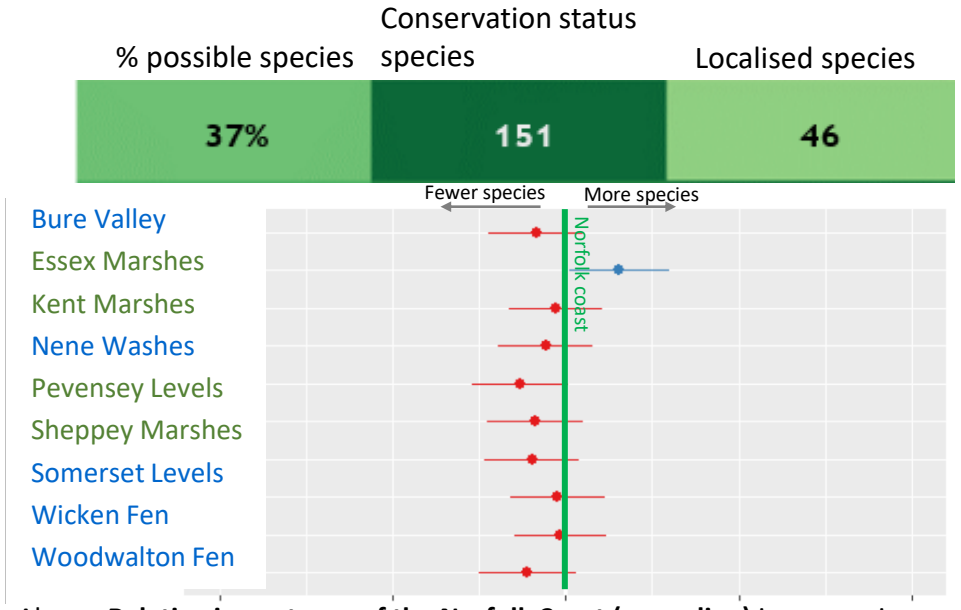


Relative numbers of priority invertebrate species compared to Norfolk Coast (green line)

The saltmarsh and brackish (sea-water influenced) habitats of North Norfolk support more priority species than other major saltmarsh complexes in England (with the exception of the Solent maritime marshes). Norfolk are as good as other major coastal grazing marshes and inland wetlands (fen) in England (except for the Essex Grazing Marshes that support more priority invertebrate species), though with the caveat that our wetland complex numbers are inflated by dune-slack species. North Norfolk sand dunes, heath and dry grassland hold more priority invertebrate species than other major dune systems in England and Wales, with the exception of Sandwich Bay (which holds similar numbers).

How to read these graphs: On each panel the vertical green line shows the value for the North Norfolk Coast; the 'whisker plots' show whether each comparator site has more or fewer priority invertebrate species (filled dot is the average, bars the confidence, note nonlinear scale). If the whiskers do not touch the green line, then we can be confident that comparator site has more (i.e to the right) or fewer (i.e. to the left) priority invertebrates than the North Norfolk Coast. For a more detailed explanation see Methods, page 44.

Grazing marsh and freshwater habitats – overall importance



Above: **Relative importance of the Norfolk Coast (green line)** in comparison to similar grazing marsh and fen sites in England, quantified in terms of numbers of important species present.

Burnham Overy marsh, Holkham NNR

Taken together, the grazing marsh and freshwater wetlands (including dune slacks, streams, spring-lines and wet features) contain an impressive amount of biodiversity, comparable to some of the best wetland sites elsewhere in England.

37% of the invertebrate species in England that use freshwater wetland habitats have been recorded within the North Norfolk Coastal Area, and the invertebrate and plant communities of these habitats include **151 species with a conservation status** and **46 Localised species**.

The Norfolk coast is of similar or greater importance for grazing marsh biodiversity as various inland wetland landscapes (such as the Somerset levels, ca. 70 Kha.), as well as smaller nationally important fen sites (such as Wicken Fen, 255 ha.) and other major coastal grazing marsh complexes. Our analysis suggests only the Essex Marshes hold significantly more priority invertebrate species (measured as species per habitat per invertebrate species group, for more details see methods).

Vange Marshes, Essex Marshes

Saltfleet Moor, Somerset Levels

Wicken Fen

Biotope importance
Major habitat types
Wet grassland
Standing water
Running water
Managing resilience

Grazing marsh and freshwater habitats

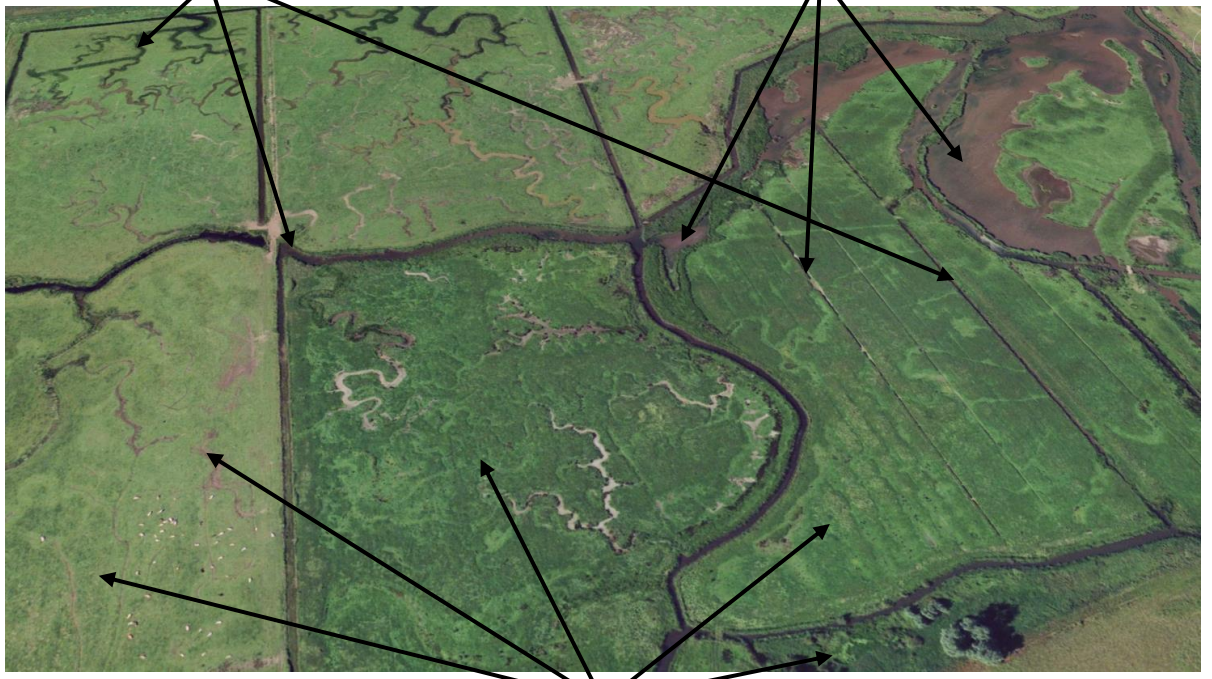
While important biodiversity is supported by both running and still water bodies and their margins within the grazing marsh mosaic, the wet grassland components support the highest numbers of priority species. However, as the majority of priority species are not shared across these habitats (Venn diagram, right) all these features are likely to be needed in order to support the full complement of important biodiversity in this biotope.

% of possible species	Conservation status species	Localised species	
47%	96	27	Wet grassland
38%	35	8	Running water
15%	15	11	Standing water

Notes: Numbers of priority species presented here exclude additional freshwater-associated species that are primarily found in acidic bog and mire habitats - are instead considered separately under 'other features'. The numbers of priority species assigned to wet grassland and standing water here may also include some species predominantly found in freshwater dune slacks.

Running water: flowing ditches, streams and spring lines

Standing water: larger wet features with still water; scrapes, ponds, pools, still ditches etc. (may be temporary)



Wet grassland: includes habitats ranging from bare ground to scattered scrub, and from damp to saturated soil conditions, also includes smaller wet features within fields (e.g. foot drains).

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Wet grassland features: importance of grazing and hydrology

In the following pages we focus on wet grassland features within grazing marsh mosaics (defined here as **grazed areas** under **wet, damp and variable** conditions, also including scrubby areas and smaller wet features such as foot drains). The specific habitat resources required by important invertebrate and plant species in these habitats are strongly influenced by both **grazing management** and **water management** in these areas. Grazing intensity (and stock types) affect both the height and structure of vegetation and also the amount of exposed bare substrate within swards and around wet features. Water levels also exert a strong influence on vegetation structure and bare ground exposure, as well as determining soil humidity.

Overall, our analysis (below) suggests that important plant and invertebrate species are found **across the full spectrum of grazing and hydrological conditions** in wet grassland. The highest numbers of important plant and invertebrate species are associated with **damp**, as opposed to fully saturated or variably damp grassland conditions – this indicates that many priority species are particularly dependent on **damp areas that experience neither excess flooding nor significant drying** within wet grassland areas. Within these damp features, larger numbers of priority species are associated with **short swards and bare ground** features (including 39 species with priority conservation status), likely associated with higher grazing intensities. However, a significant number of priority species are associated with **tall and shrubby swards** within wet grassland across a range of hydrological conditions, suggesting that a mix of low and high grazing intensity may optimise habitat provision.

Clubonia frisia, a nationally rare spider of wet grassland associated with short swards, bare earth and variable humidity

	% of possible species	Conservation status species	Localised species
SATURATED	50%	8	0
VARIABLE	55%	10	2
DAMP	42%	39	4

Short with bare ground

	% of possible species	Conservation status species	Localised species
SATURATED	36%	7	0
VARIABLE	55%	11	6
DAMP	36%	19	0

Tall or scrubby sward

Higher to lower grazing Intensity

Hahnia pusilla, a nationally scarce spider requiring taller and/or scrubbier conditions in wet grassland on damp substrates

Biotope importance
Major habitat types
Wet grassland
Standing water
Running water
Managing resilience

Wet grassland: creating biodiverse vegetation mosaics through varied grazing management

Short sward and bare ground

A large number of important plant and invertebrate species are supported by wet grasslands grazed to short swards with bare ground (top left), which is currently a prevalent *status quo* management prescription intended to deliver in particular for flagship wading birds such as Lapwing *Vanellus vanellus*. Importantly, substantial numbers of important plants and invertebrates require **very different conditions** in wet grasslands, particularly areas with tall, varied and scrubby swards (bottom left) in both wetter and drier conditions.

Our results suggest that wet grassland sites featuring areas with **multiple sward heights**, each spanning a range of water regimes, could provide resources for **41% more important plant and invertebrate species** (107 vs 63) than sites with homogenous short swards and bare ground. Such mosaics could be supported by a mixed grazing approach, where stock densities and types were varied in both time and space to produce a mosaic of sward features. Benefits to biodiversity could be accrued if this grazing variability were implemented at various spatial scales, from small (i.e. within field variation) to medium (within site variation) to large (between site variation across the landscape as a whole).

Mosaic of short and tall swards, bare ground and scrub

Management options:

- Varied grazing intensities are needed in order to provide resources for many priority species in wet grasslands
- Variation in grazing could include different stock densities, stock types and alterations to the timing of grazing
- Optimal management would provide shorter and taller swards at various spatial scales across the hydrological spectrum

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Wet grassland: potential importance of floral diversity within taller wet grass swards

Examining what we know about the feeding requirements of important invertebrate species can provide useful information on the **fine-scale habitat resources** they require within broader landscape features. For a subset of important wet grassland invertebrate species for which we know their feeding guild (from Pantheon) we see in particular that species feeding directly on plants (see table below, nectarivores = feeds on nectar from flowering plants, herbivore = feeds on plant tissues) are over-represented among priority species associated with tall and scrubby swards in wet grasslands.

This suggests that some important invertebrate species that are found in areas with taller swards may be particularly dependent on specific plant species found within those conditions, in addition to having the appropriate physical structure of the vegetation. Therefore, more florally diverse tall swards may be particularly important within wet grassland in order to support a wider range of priority species. Grazing management could therefore include measures to encourage a **greater diversity of plants** (particularly flowering plants) and avoid domination by a few rank species – including more varied grazing regimes (e.g. altered timing of grazing, mob grazing), and use of breeds that can help control rank wetland vegetation (e.g. belted Galloway cattle).

Orthonoma vittata, a section 41 priority species associated with taller swards in wet areas, is a herbivore of bedstraws (*Galium* spp.)

Bombus ruderatus, a section 41 priority species associated with tall or scrubby wet grassland rich in flowers (particularly Lamiaceae, Fabaceae, Asteraceae)

Longitarsus ganglbaueri, a nationally scarce beetle associated with short swards on wet grassland with variable humidity, is a herbivore of ragworts (*Senecio* spp.)

Ochrosis ventralis, a nationally rare flea beetle requiring wet grasslands with taller and scrubbier conditions with variable humidity

Feeding guild	Short + bare ground	Tall + scrub
Nectarivore	0	7
Herbivore	1	5
Predator	4	9
Saprophage (detritus)	3	0

Management options:

- Reduced grazing intensity in some areas, or mob grazing, can give taller swards with a diverse set of flowering plants
- Reducing grazing particularly in areas that have previously received lower nutrient inputs may be valuable for floral diversity (e.g. areas never previously farmed as arable)

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Wet grassland: Water management and soil humidity

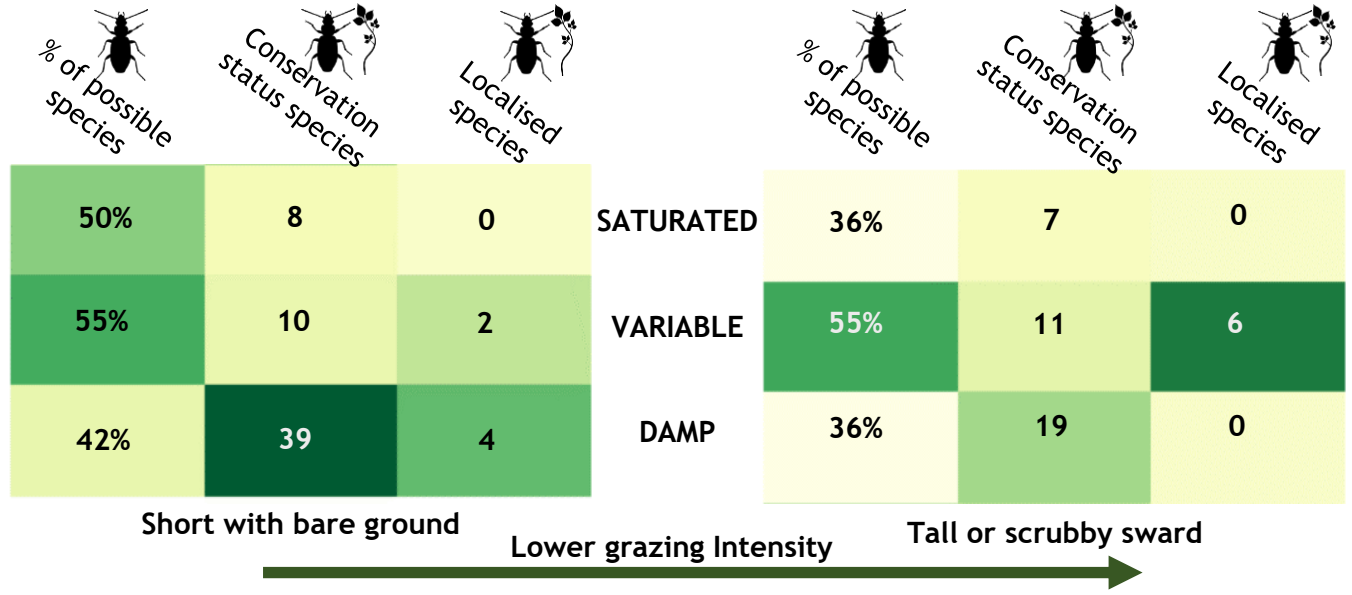
Podagrica fuscipes, a nationally scarce flea beetle found in taller wet grassland swards with scrub and variable humidity

Radiola linoides, a Vulnerable specialist of low-nutrient wet grass and dune slacks

Here we consider wet grassland species according to their hydrological requirements. In our typology, 'saturated' habitats refer to wet grassland areas that typically have water at or above the surface; damp soils have a high water table but are rarely have water pooled at the surface (although water may well up underfoot); those with variable humidity transition from saturated to drier conditions through the year.

On the Norfolk Coast, damp soils within wet grassland support more priority species than saturated or variable soils, particularly in more intensively grazed areas with short swards and bare ground. Wet grassland features with saturated or variable soil conditions do, however, support relatively high percentage representations of all English species associated with those features, suggesting that they are good examples of that kind of assemblage in a national context.

Overall, our results highlight the importance of maintaining a **range of hydrological conditions** within grazing marsh complexes, including saturated, damp and variable areas as well as varied sward heights.



Myosurus minimus, nationally scarce wet grassland specialist of short, bare swards with variable humidity

Management options:

- Manage drainage to promote a range of hydrological conditions within wet grassland including some permanently waterlogged areas, some permanently damp areas and some that are seasonally dry
- Implement varied grazing regimes across the full spectrum of hydrological conditions

Biotope importance
Major habitat types
Wet grassland
Standing water
Running water
Managing resilience

Standing water features: Varying intensities of grazing disturbance at margins

Larger standing water features within grazing marshes include pools, scrapes and ponds. Our results suggest that **shallow open margins** of these features (dominated by mud and litter) support large numbers of important plant and invertebrate species (15) – features that can be promoted by disturbance through more **intensive grazing**. Significant numbers are also supported by margins with higher levels of emergent vegetation. This means that variations in local grazing pressure (through moving livestock, partitioning grazing units, or restricted accessibility) again may be important for biodiversity in standing water features, allowing some margins to develop dense margin vegetation or emergent wetland vegetation alongside sparsely vegetated and open margins

'Wetland' vegetation here refers to tall grazing intolerant species such as Bullrushes, Irises, Reeds, Sedges, *Glyceria* etc.

Sparse | Dense

Vegetation in this context is considered 'dense' rather than 'sparse' here when it covers the substrate.

Mud and litter is often associated with heavy grazing and trampling at wetland margins, though species associated with this feature may also be associated with heaps of dead vegetation.

Greater grazing intensity ↓

	% of possible species	Conservation status species	Localised species
Mud and litter	34%	8	7
Sparse vegetation	36%	6	0
Dense vegetation	45%	8	0
'Wetland' vegetation	36%	8	0

Management options:

- priority species require both open and well-vegetated margins, which could be achieved by varying grazing pressure
- A mix of disturbed and mature vegetation structures around freshwater features will support the biggest range of priority species

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Running water: Profile and channel morphology may be more important than vegetation structure

Our results suggest that larger numbers of important plant and invertebrate species depend on the micro habitats associated with the substrate conditions at the margins of running water (seepages, exposed sediments, mud/shallow litter) than with the vegetation growing within the water.

This suggests that, where possible, flowing ditches could support more biodiversity if reprofiled to be **wider with shallower slopes**, creating more of these exposed margin habitats. Since the energy of flowing water creates and maintains some of these habitats through erosion (seepages, exposed sediments), drainage systems featuring more natural curved and branching channels may also help create and maintain these conditions.

% of possible species	Conservation status species	Localised species	
20%	3	0	running water; wetland vegetation
13%	7	3	running water; seepages
9%	1	5	running water; exposed sediments
17%	2	3	running water; drawdown zone: mud/shallow litter

Management options:

- Most priority species are found at the eroded margins of running water, suggesting that a shallow profile would increase the coverage of key micro-habitats.
- Restoring pre-drainage creek systems may provide more natural and biodiverse aquatic features while also increasing resilience in case of tidal inundation (see page 32).

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Resilience and water quality

Drainage ditches, scrapes and pools offer different opportunities for species even where vegetation structure is similar.

Larger scrapes and waterbodies can be turbid and relatively nutrient-rich, while clear, high-quality (lower nutrient) water is more often found near freshwater inflows to grazing marsh, particularly at landward springlines.

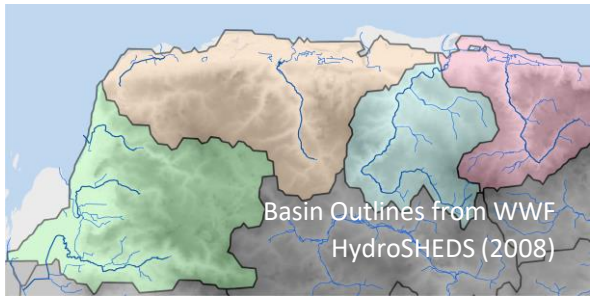
Analysis of wetland species' micro-habitat and management needs considered grazing intensity and the structure of marginal and wetland vegetation (mud and litter, sparsely- or well-vegetated). However, Pantheon did not distinguish whether a particular species would be found in such structures if this was in a drainage ditch, small open water feature, or a larger scrape, pool or water body.

Waders and herbivorous wildfowl feed in productive wetlands with abundant (high biomass, high productivity) readily-accessible food. In contrast, greater numbers of scarce or threatened plant and invertebrate species are generally found in wetland habitats with lower nutrient levels [1, 2, 3]. A primary focus on birds may, therefore, fail to deliver the full range of wetland conditions needed for priority biodiversity.

While we acknowledge uncertainty in what type of wet features different wetland species recorded from the study area may utilise, a precautionary approach would be to ensure a range of contrasting open water and ditch features. Biodiversity will also be enhanced by reducing direct and diffuse nutrient input to grazing marsh and wetland complexes.

Common Water-crowfoot *Ranunculus aquatillis* may indicate better water quality

Norfolk coast catchments



Recommendations and management options

Conducting a landscape-scale audit of the sources, amount and quality of freshwater flowing into different coastal sections could support strategic prioritisation of wetland management. Water quality can be assessed by biotic scores, environmental criteria or chemical analysis.

Sensitive management of arable farmland and watercourses that are landward of or adjacent to grazing marsh or coastal wetland, could reduce sediment and nutrient run off.

Within grazing marsh and coastal wetland complexes, diverse wet features should be prioritised close to landward spring-lines or freshwater inflows.

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

[1] Fuller et al. (2017) Human activites and biodiversity opportunities in pre-industrial cultural landscapes: relevance to conservation. *Journal of Applied Ecology*, **54**, 459-469; [2] Fen management handbook; [3] Rodwell (1995). *British Plant Communities. Volume 4: Aquatic Communities, Swamps and Tall-herb Fens*. CUP, Cambridge.

Resilience and adaptation to saline incursion

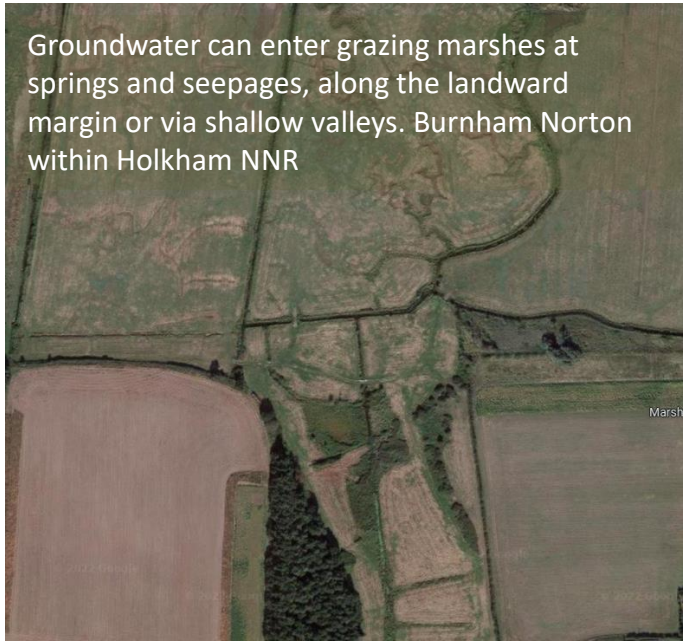
Coastal grazing marshes were formed by reclaiming saltmarsh and saline silt, but were colonised by a rich freshwater biodiversity. However, this is now threatened by sea flooding.

The resilience of this freshwater wildlife may be enhanced by management to hold, pool and retain high-quality freshwater as a resource and direct this to areas less influenced by saline seepage or at lower risk of overtopping. An example is the bunding of landward freshwater habitats at Pope's Marsh within the Cley-Salthouse complex.

Potential water management in grazing marsh to enhance resilience to saline flooding

If practicable, landward **spring line sources** of freshwater could be bunded and drainage systems modified to direct flows along rather than down contours, ideally flooding slightly higher-lying landward sections of grazing marsh complexes, rather than channelling water directly towards sea wall sluices or into parts of the marsh complex likely to become estuarine or tidal creeks following major breaches.

A highly engineered example of this principle, formed the basis of the original water management system at RSPB Titchwell Marsh reserve (see opposite).


Groundwater can enter grazing marshes at springs and seepages, along the landward margin or via shallow valleys. Burnham Norton within Holkham NNR


Clear groundwater bubbles up from the aquifer at springs. Old Hunstanton.

At RSPB Titchwell Marsh, freshwater flowing into Church Marsh that would drain into the tidal saltmarsh was instead routed to the freshwater marsh created to the west

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Resilience and adaptation to saline incursion

Seven rivers feed into the coastal plain, most are chalk streams or chalk-fed, and all have diverse habitats with important biodiversity in their upper reaches. However the lower reaches of most of these rivers are impacted (by canalisation, nutrient enrichment), reducing biodiversity connectivity and water quality.

River Hun
Short chalk stream with outfall at Holme Dunes NNR

River Burn
Chalk-fed highly-modified river with outfall at Burnham Overy, Holkham NNR

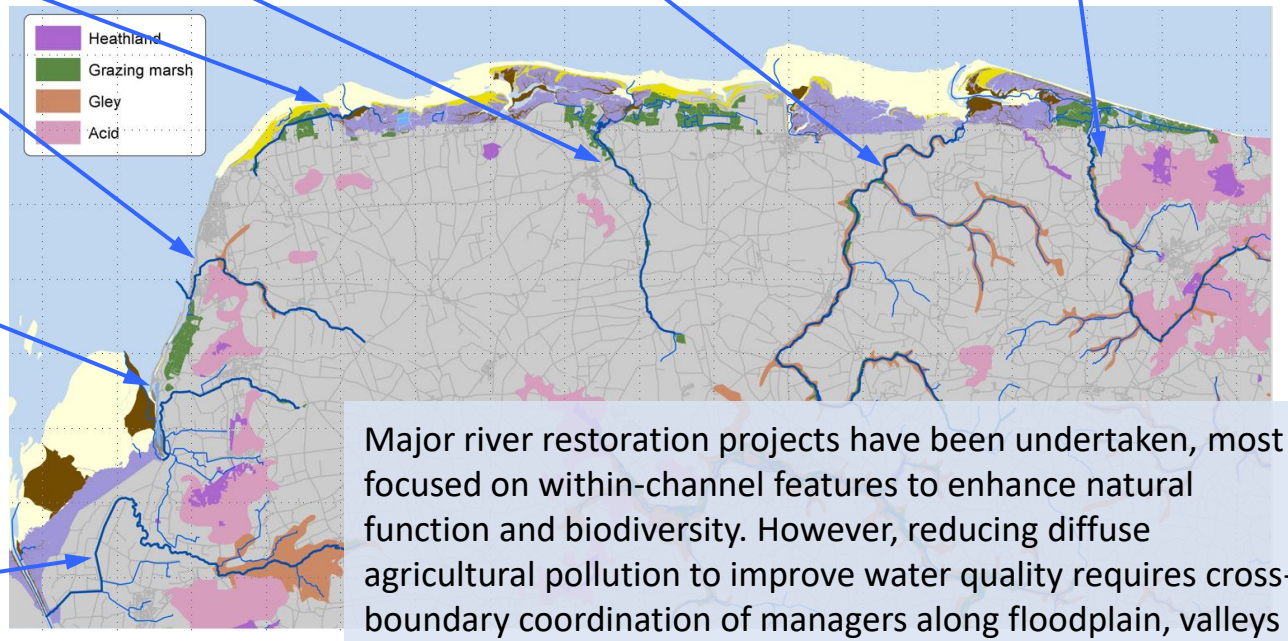
River Stiffkey
Longer river flowing over sand gravel and chalk bedrock, outfall through Stiffkey Fen SSSI.

River Glaven
Flows through arable, plantations meadows and wetlands with outfall into Blakeney Marshes

River Heacham
Chalk-fed river potentially affected by abstraction in the upper catchment

River Ingol
Chalk stream, lower reaches impacted by intensive arable, outfall near Snettisham RSPB reserve

River Babingley
Chalk river, whose lower reaches are embanked and affected by sediment, enters Great Ouse at Wootton Marsh



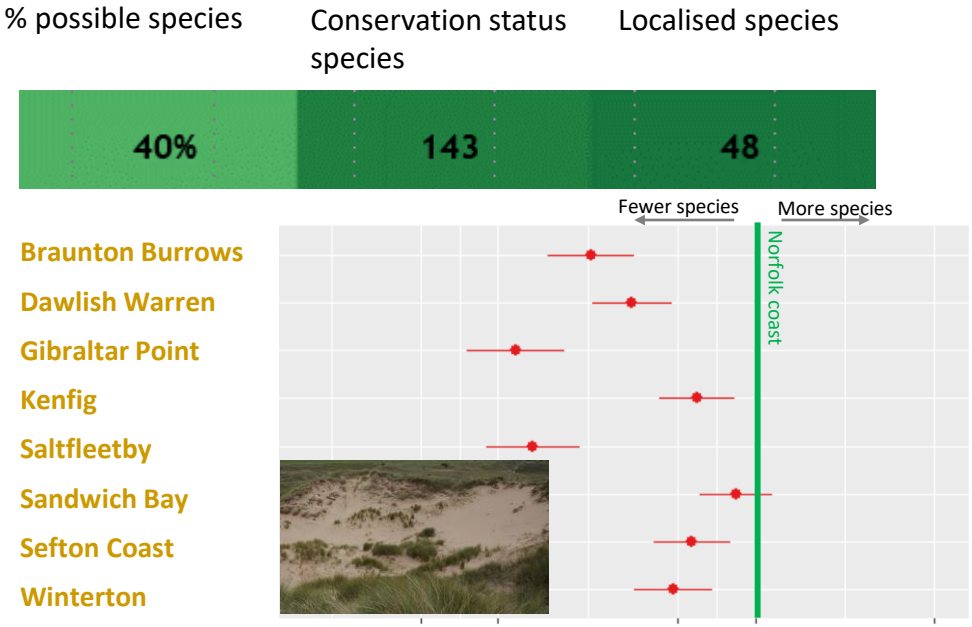
Major river restoration projects have been undertaken, most focused on within-channel features to enhance natural function and biodiversity. However, reducing diffuse agricultural pollution to improve water quality requires cross-boundary coordination of managers along floodplain, valleys and at catchment-scale to facilitate transformative change.

Landscape partnership with inland managers along the rivers and chalk-streams feeding into the coastal plain, could aim to restore their floodplains to wet grassland, grazing marsh, riparian woodland and other wetlands, and valley-sides to permanent grassland or wood pasture, enhancing water quality and biodiversity.

This may benefit down-stream wetlands through reduced nutrient and sediment loading, and offer mitigation for saline flooding of coastal wetlands.

Biotope importance | Major habitat types | Wet grassland | Standing water | Running water | Managing resilience

Dune, heath and shingle habitats – overall importance



Relative numbers of priority invertebrate species at important sand dune sites compared to Norfolk Coast (green line)

The Norfolk Coast's **dune, heath and dry grassland** habitats contain a wealth of important biodiversity. 40% of all species in England that use such habitats are known from the North Norfolk Coastal Area, including **143 species with a conservation status** and **48 Localised species**.

According to our analysis, the North Norfolk Coastal Area has significantly more priority invertebrate species than most other nationally important comparator coastal dune landscapes, including large (such as the Sefton coast SAC, 4592 ha) and smaller (e.g. Kenfig, 526 ha; Winterton, 423 ha.) complexes, and is similar to the otherwise best site in England (Sandwich Bay in Kent).

Birkdale dunes, Sefton coast

Remobilised dunes, Kenfig

Dune slack, Burnham Overy

Biotope importance
Major habitat types
Vegetation & disturbance
Conifers on dunes
Dune slacks

Major habitat types within dunes and dune-shingle complexes

Dune systems are highly diverse and support a wide range of rare and important species, many of which are specifically adapted to challenging low-nutrient, arid or salt-laden environments. Dune species communities also overlap with those of lowland heaths, and important species can occur in both dunes and inland heath (or other dry open habitats) within the study area.

Extensive dune and shingle landscapes have developed providing a dynamic natural coastal barrier defence along the North Norfolk coast[1].

The NE inventory recognises **541 ha of coastal sand dune** within the study area; an additional major complex at Winterton will be considered in subsequent auditing.

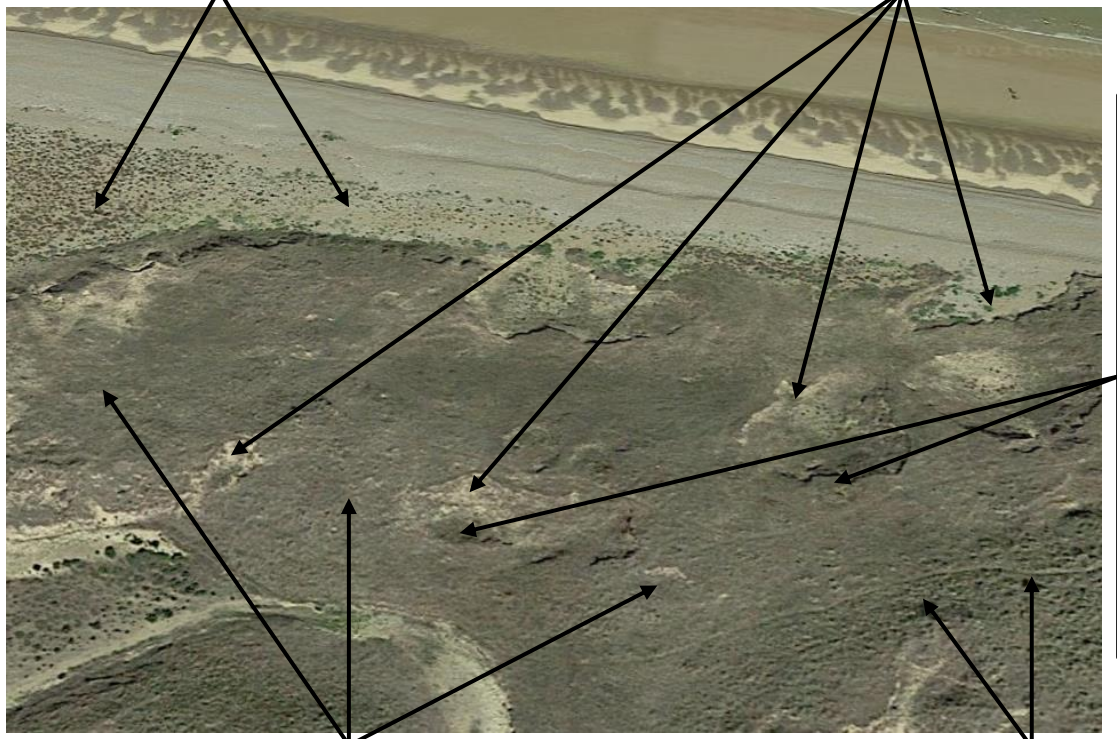
Landscape vision:

Where possible, resilience of dune biodiversity may be enhanced by creating large-scale linkages between coastal dune landscapes to inland heaths, which share many of the same important plants and invertebrates. This could be achieved by creating e.g. ruderal strips along sandy field boundaries, hedges or trackways across the low-lying coastal plain.

Additional heathland and heath-wood pasture could also be created, particularly on former plantation land, increasing the landscape scale resilience of dune-heath species assemblages.

Shingle: bare and vegetated areas on coarse shingle substrate

Exposed sand: mobile and dynamic resource present in pioneer dunes, and in fixed dunes where blowouts, notches and disturbed patches allow sand mobility.



Dune slacks: damp and wet freshwater or brackish depressions, including pioneer slacks and more permanent features on fixed dune areas that are vulnerable to succession

Short sward and bare ground: diverse fixed (grey) dune and lichen pasture, maintained by grazing (rabbits or stock) and deposition of wind-blown sand from notches or yellow dune.

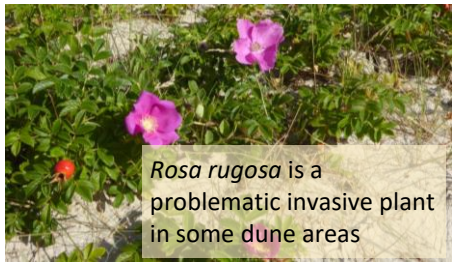
Tall swards: taller grasses and scrub (e.g. bramble, sea buckthorn and invasive *Rosa rugosa*) develop and can gradually dominate fixed dunes, in a transition to scrub woodland

Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

[1] notably at: Holme Dunes, Titchwell-Brancaster; Scolt Head Island NNR; Burnham Overy & East Hills within Holkham NNR.

Mobile, dynamic dunes are essential to support important dune species

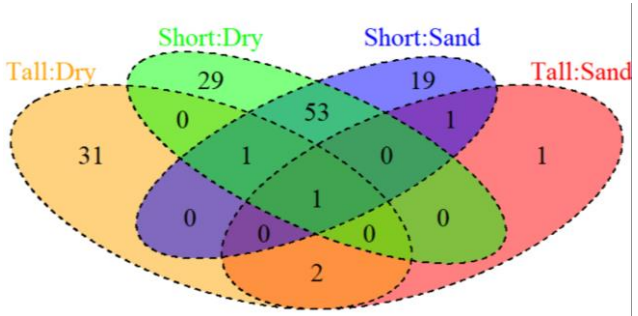
Numbers of species with conservation status and localised species are greatest in dynamic dune habitats that feature **short swards with bare ground and exposed sand**. These resources occur in both pioneer (yellow) and fixed (grey) dunes, but can be lost to successional encroachment by tall swards and scrub if not maintained by disturbance (see Threats). Nearly three times as many priority species are associated with disturbed, early-successional dune conditions than fixed and heavily vegetated conditions. Fixed, mature and well-vegetated dune habitats are an important part of dune complexes, but active management to maintain dune mobility and prevent whole systems becoming dominated by tall swards and scrub is an important priority.



Rosa rugosa is a problematic invasive plant in some dune areas

	% of possible species	Conservation status species	Localised species
Tall or scrubby, with exposed sand	36%	3	1
Tall or scrubby, with dry substrate	40%	29	6
Short and bare ground, with exposed sand	42%	46	43
Short and bare ground, with dry substrate	39%	52	46

Associations of unique priority species (both those with conservation status and localised species) with different dune characteristics



34 species need tall swards and scrub
but 101 species need short and bare dune conditions

Threats to dune habitats

Dune habitats are increasingly threatened by various pressures:

- Nutrient deposition – long-term increases in atmospheric nutrient levels mean vegetation growth and dune fixing happens more quickly. Nutrients arrive in dunes from the atmosphere, as well as direct sources (e.g. livestock & dog faeces) and nitrogen fixing plants including Sea Buckthorn, that together promote the establishment of ruderal flora rather than dune specialists
- With climate change, milder and wetter winters promote faster vegetation growth, as does rising CO2 concentration in the air, speeding up dune stabilisation and growth towards taller and scrubbier vegetation
- Invasive introduced species such as *Rosa rugosa* can rapidly spread and out-compete native dune flora

Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

Managing dynamic dune habitats

Historically, conservation management of dunes nationwide tended to focus on protecting these fragile systems from perceived threats of erosion and disturbance. However, this led to widespread dune stabilisation, and in many areas the wholesale loss of important bare sand and early successional habitats.

The importance of frequent disturbance and sand mobility for dune biodiversity is now widely recognised, and management focusses on ensuring that dune complexes maintain a spectrum of early, mid and late successional habitats. Healthy dune mosaics in the UK are thought to typically have at least 10-15% bare sand and 30-40% pioneer dune habitats[1].

Management options: Maintaining early-successional dune habitats

Key processes that maintain short swards and bare, exposed sand resources in dunes are a) **grazing** and b) **deposition of wind-blown sand**. Both processes are likely to be necessary to combat the increasing threats posed to dune habitats by growing atmospheric nutrient deposition and consequent scrub encroachment.

Paddock grazing by livestock - especially hardy breeds such as konik ponies – is effective in slowing dune succession and can also increase sand mobility through direct ground disturbance. Grazing must be carefully controlled/monitored using electric fencing/GPS collars to ensure appropriate levels and patterns of disturbance across sites.

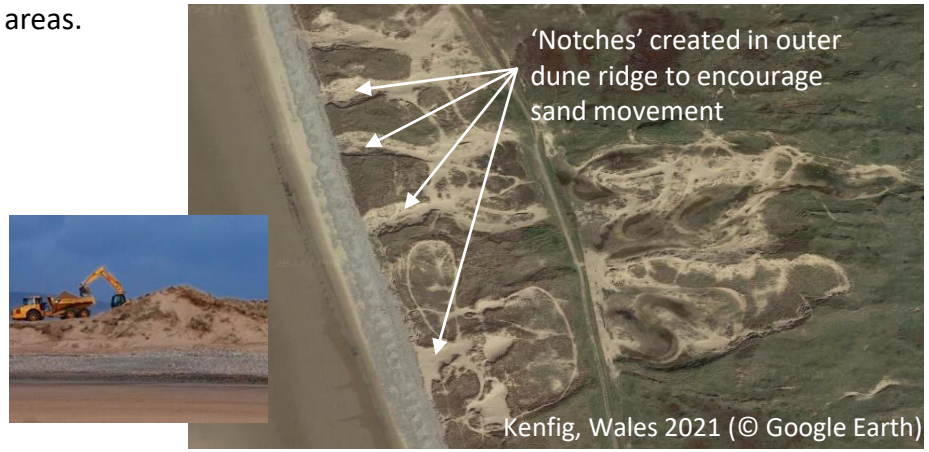
Rabbit grazing should be encouraged wherever possible – but may be challenging with restored buzzard populations.

Management options: Sea Buckthorn

Sea Buckthorn encroachment can be problematic in dune systems – this species 'fixes' nitrogen from the atmosphere, meaning that areas surrounding mature stands can become unsuitable for specialist dune flora due to nutrient enrichment. Removal of mature patches is difficult and costly – management should focus on removing new patches & holding expanding growth in check[2].

Management options: Restoring degraded dune systems

Where early- and mid-successional dune habitats have been lost wholesale to vegetation encroachment, mechanical disturbance may be needed. At various sites in Wales, turf stripping has been used to restore dune habitats, combined with creation of notches in frontal dune ridges to increase wind-blown sand deposition into fixed dune areas.



Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

[1]Litt et al. 2021 *British Wildlife* 33, 106-116.
[2]Richards & Burningham 2011 *Journal of Coastal Conservation* 15, 73-85.

Coniferous woodland – little important biodiversity specifically needs pines on dunes

Some sections of Norfolk coastal dunes were historically stabilised by planting pine woodland, although other coniferous areas occur inland. Comparing the number of priority species associated with coniferous woodland with those of the open dune (and heath) habitats, shows the 'opportunity cost' of retaining coniferous woodlands instead of restoring either mobile or fixed dunes. Of the few priority species directly associated with coniferous woodlands, none appear to rely on conditions particular to dune conifers and many are also found inland in other wooded habitats.

European Antlion (*Euroleon nostras*) larval pits

Antlion larvae
photo B Schoenmakers

Goodyera repens

Important invertebrate species of the Norfolk coast area, associated with conifers

Species	Guild	Group	note
Dromius angustus	Arboreal	Beetle	Found inland incl. plantations
Hapleginella laevifrons	Arboreal	Fly	Found inland
Anthocoris butleri	Arboreal	True bug	Under-recorded, found in inland gardens
Cydia conicolana	Arboreal	Moth	Found inland incl. Dersingham
Chrysopa dorsalis	Arboreal	Lacewing	Found inland
Arhopalus ferus	Decayed wood	Beetle	Found inland
Arhopalus tristis	Decayed wood	Beetle	Found inland
Pityogenes trepanatus	Decayed wood	Beetle	Found inland
Eucinetus meridionalis	Decayed wood	Beetle	Found inland
Sepedophilus lusitanicus	Decayed wood	Beetle	Found inland

Some charismatic species found exclusively in pine covered dunes in the study area do not qualify as 'priority species' in this analysis. Creeping Lady's-tresses, *Goodyera repens* is widespread in eastern Scotland (RedList Least Concern) and European Antlion, *Euroleon nostras* (also found in the Suffolk Sandlings, RedList status not yet evaluated) are both exciting and locally unusual, do not have a national conservation status nor significant localisation to the Norfolk Coast. Moreover, the habitat resources they require do not appear to be shared by many other important species in the area.

Management options:

- Open dunes support many more priority species than coniferous woodlands – **recreating open dune systems by removing woodland** could increase opportunities for biodiversity, while helping natural dune migration to enhance coastal protection[1].
- Key areas under mature conifers that support priority species (including *Monotropa hypopitys)* should be retained and protected.

[1] Environment Agency Shoreline Management Plans emphasise the risk that rising sea levels can cause the frontage of fixed / stabilised dunes to erode, in contrast allowing or encouraging their dynamic migration by mobilising the dunes, protects their depth and thus flood protection capacity

Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

Coniferous woodlands on dunes support far fewer priority species than open dune habitats

Important biodiversity associated with coniferous woodland on Norfolk Coast sand dunes:

	% of possible species	Conservation status species	Localised species
Shaded floor	13%	1	0
Decaying wood	15%	2	6
Arboreal	33%	2*	4
Total:	25%	5	10

Yellow Birds-nest *Monotropa hypopitys*, a saprophytic plant that depends on fungal communities around tree roots, is a Section 41 Priority species (localisation 1.5%). On base rich soils it can be found on shaded forest floor under Beech and Hazel, whereas in the NNC area it is found on dunes under mature pines.

Management options:

- Open dune habitats support many more priority species than coniferous woodlands – restoring some wooded areas to mobile dynamic dune systems would support many more priority species.
- Mobilising dunes through tree removal to allow landward movement can also sustain their flood defence function.

Important notes:

1. A limitation of this audit relates to Fungi, for which comprehensive habitat guilding is not possible due to limited data. Any future actions to restore open dunes through removal of conifers should be underpinned by detailed surveys for priority species, including Fungi, to ensure that any wooded parcels supporting priority species (particularly under older Pines) are retained and protected.
2. Our consultation with local natural history experts gave no indication that any conifer-associated invertebrate species in the study area rely specifically on conifers on dune settings. Many could also be supported by suitable habitats on the landward part of the study area.

Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

* Includes recent UK colonist

Dune slacks

Freshwater dune slacks are a highly important component of dune systems supporting many priority species. Slacks occur in both pioneer and fixed dunes, and like other dune habitats are highly vulnerable to vegetation encroachment and nutrient deposition (both atmospheric and direct from livestock). Many important dune slack species also require disturbance and bare substrate exposure around slack margins – particularly rare plants such as the flagship liverwort Petalwort *Petalophyllum ralphsii.* Slacks may also be threatened by changes in groundwater quality, including diffuse nutrient enrichment or pollutants entering from elsewhere in the catchment. Brackish slacks occur in seaward areas of dune systems, and tend to be less diverse than freshwater features, though they do support a small number of additional priority species (see p 39).

Dune slack before (upper) and after (lower) scrub removal at Talacre, Wales (reproduced from Rhind & Jones 2009)

Newly engineered 1 ha slack at Kenfig NNR, Wales © Scott Hand

Petalwort *Petalophyllum ralphsii* is a specialist liverwort species only found in damp calcareous dune slacks that requires open conditions created by grazing or physical disturbance

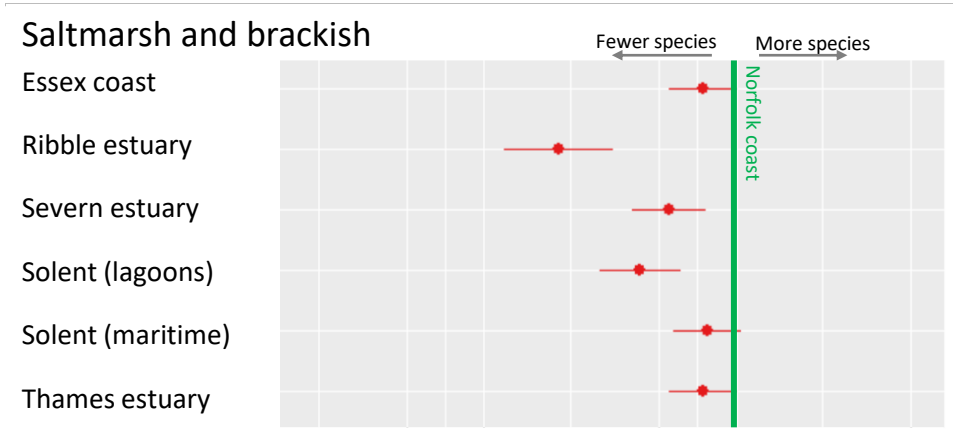
Management options:

- Restore open conditions to mature heavily-vegetated slacks through mechanical scrub removal
- Allow limited disturbance by grazers (e.g. konik ponies), but avoid excess direct nutrient deposition by livestock
- Turf-stripping to create bare ground and exposed mud/sand
- Creation of new slacks and pools through mechanical scraping

Biotope importance | Major habitat types | Vegetation & disturbance | Conifers on dunes | Dune slacks

Saltmarsh and Brackish habitats – overall importance

% possible species	Conservation status species	Localised species
53%	54	101



Important invertebrate biodiversity relative to the Norfolk Coast

The saltmarsh and brackish habitats of the Norfolk Coast hold more important biodiversity than many nationally important comparator sites and are **as good as the best saltmarsh sites in the country**.

53% of all species in England that use such habitats are known from the North Norfolk Coastal Area, including **54 species with a conservation status** and **101 Localised species**.

With c. 3,900 ha of saltmarsh, the Norfolk Coast has significantly more priority invertebrate species than most comparator sites – including nationally important estuarine saltmarsh systems, such as the Thames (5,289 ha.) and Severn (1,400 ha.) estuaries and nationally important coastal saltmarshes such as in Essex (3,376 ha.). Only the Solent maritime marshes have similar numbers of priority invertebrates according to our analysis[1].

Tanner's lake, Solent maritime

Andrew's Pant, Severn estuary

Thames estuary

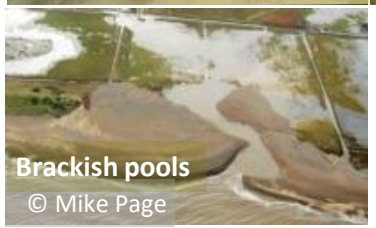
Biotope importance
Major habitat types
Saltmarsh
Sandy beach
Brackish features

[1] measured as species per habitat per invertebrate species group for more details see methods, page 44

Saltmarsh and brackish major habitats overview

The saltmarsh biotope includes a range of intertidal habitats spanning the vegetated marsh itself, together with creeks and saline pools, sandy beaches and brackish features. The latter include pools and seepages where freshwater flows into the intertidal zone, as well as pools on higher marsh areas that are partially fed by rainwater. Across the Saltmarsh and brackish biotope, the majority of priority species are found within the intertidal saltmarshes themselves. Brackish habitats and sandy beach habitats also support significant biodiversity in terms of priority species, especially localised ones.

% of possible species	Conservation status species	Localised species	
43%	5	26	Sandy beach
58%	23	61	Saltmarsh
51%	7	6	Brackish



Biotope importance
Major habitat types
Saltmarsh
Sandy beach
Brackish features

Note: Although many strictly marine species use these and estuarine habitats at high tide, their requirements are not analysed in this report.

Saltmarsh habitat management

Norfolk coast saltmarsh habitats support large numbers of priority species and invertebrate assemblages that are highly representative of the complete English saltmarsh fauna. The most representative invertebrate assemblage, with the highest proportion of the possible England species (64%) is associated with the tidal litter left on the strand line, whereas the largest numbers of priority (15) and localised (34) species are associated with saltmarsh vegetation. While it is tempting to interpret these Pantheon micro-habitat groups as representing different **saltmarsh zones**: lower (substrate), mid (vegetation) and upper (strand line) marsh. However, consultation with local natural history experts suggests these groups of species and their particular microhabitats may be found across the full gradient of the marsh.

The high biodiversity value of Norfolk saltmarsh likely depends on:

- a large area of saltmarsh habitat (c3,900 ha) much of which is ancient / long-established;
- vegetation that covers a complete range of zonation, from mudflat and pioneer saltmarsh to upper saltmarsh, while in many sections the upper margin merges into dune or terrestrial habitats and is not constrained by a hard engineered boundary. Together, this provides a full range of zones, niches and micro-habitats and also offers an invertebrate refuge from flooding at the highest tides;
- vegetation and saltmarsh flowers are not grazed by livestock, offering abundant nectar, pollen and seeds;
- saltmarshes have developed behind coastal dune and barrier islands without receiving deposits of enriched estuarine sediments (that can encourage invasion by Cordgrass).

	% of possible species	Conservation status species	Localised species
Strand line	64%	8	19
Substrate	54%	11	13
Vegetation	57%	15	34

Saltmarsh grazing:

Most Norfolk saltmarshes have been ungrazed by livestock for over a century. A review of saltmarsh research[1] found livestock grazing alters saltmarsh soil and sediment properties, and **reduces invertebrate richness**, particularly of herbivorous invertebrates (that in turn may affect fish feeding on the saltmarsh) but can increase plant diversity. Livestock grazing **greatly reduces bee richness and abundance**[2] by removing upper saltmarsh flowers of species such as Sea Aster *Tripolium pannonicum* and Sea-Lavender *Limonium spp.* that are also important to other groups including Diptera. In contrast natural grazing by wintering geese appears to maintain habitat heterogeneity.

Contributors to the saltmarsh workshop also emphasised the problems in limiting livestock impacts on grazed saltmarsh to low or moderate levels, as livestock tend to concentrate activity in limited areas of more easily accessible upper marsh.

Biotope importance | Major habitat types | Saltmarsh | Sandy beach | Brackish features

[1] Davidson et al. (2017). Livestock grazing alters multiple ecosystem properties and services in salt marshes: a meta-analysis. J. Applied Ecology 54, 1395-1405.
[2] Davidson et al. (2020) Grazing reduces bee abundance and diversity in saltmarshes by suppressing flowering of key plant species. *Agri. Ecosyst. Environment* 291, 106760.

Saltmarsh re-creation through managed realignment

Under most predicted scenarios of sea level rise, the realignment (managed or otherwise) of further coastal defences in the Norfolk Coast area is almost inevitable within the next 20-50 years. Sea defence failure poses a **major threat to biodiversity** and livelihoods in the region, but managed realignment schemes have the potential to increase the provision of valuable saltmarsh habitats for biodiversity and to increase coastal resilience to flooding.

The alternative approach, 'holding the line' through maintenance and enhancement of existing defences, is essential in protecting high value freshwater grazing marsh habitats. However, this approach brings the risk of unplanned and unmanaged catastrophic saltwater incursion into these habitats when defences eventually fail. Estimates suggest that typical storm surge heights along the Norfolk Coast may increase by more than 1m by 2100[1]. Regular unmanaged saltwater incursion could have serious negative consequences for biodiversity in low-lying freshwater grazing marsh habitats. Managed realignment of sea defences landward to areas where the risk of failure/overtopping is reduced, can improve protection of freshwater habitats inland of the new defences. This was successful at Titchwell Marsh realignment[2].

Managed realignment:

Managed realignment trade-offs

Decisions about managed realignment must carefully consider the potential loss of important grazing marsh biodiversity, as realignment on the Norfolk Coast will generally mean replacement of existing freshwater grazing marsh habitats with restored saltmarsh. This Biodiversity Audit indicates both biotopes support comparable levels of nationally-important biodiversity:

	% possible species	Conservation status species	Localised species
Saltmarsh	53%	54	101
Grazing marsh	37%	151	46

Importantly, newly-created saltmarsh habitats are not guaranteed to support these priority species, and it may take decades before restored marshes support comparable species communities to existing saltmarsh. The potential loss of grazing marsh biodiversity from managed realignment must, however, be balanced against the risks to the same freshwater biodiversity of unmanaged saltwater flooding if/when existing sea defenses fail. Landscape-scale restoration of river valleys may contribute to mitigating this loss (see Grazing Marsh: Managing resilience)

Key management considerations for saltmarsh restoration:

- Saltmarsh restoration or re-creation through managed coastal realignment, or by allowing natural roll-back, is an important option in managing future land-use change on the Norfolk Coast.
- Priority areas for managed realignment are low-lying grazing marsh zones at risk of tidal incursion, and biodiversity benefits are likely to be highest on sites with unmodified natural drainage systems.
- Previously arable sites with underlying clay pipe field drains are of lower priority for realignment, as tidal scouring of gravel drain beds can result in regular parallel, not dendritic, creek systems resulting in increased waterlogging and *Spartina* dominance.
- Creating or restoring dendritic creek systems in current grazing marsh, as well as infilling existing drainage ditches, will enhance their ecosystem function if and when they return to saltmarsh

Biotope importance | Major habitat types | Saltmarsh | Sandy beach | Brackish features

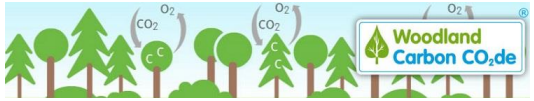
[1] Muis et al. (2020) *Frontiers in Marine Science* 7, 263.
[2] Titchwell Marsh Coastal Change Project: Layman's Report, Layman's Report (rspb.org.uk)

Carbon sequestration and carbon finance through saltmarsh re-creation

The saltmarsh habitats of the Norfolk Coast have extremely high value for both biodiversity and ecosystem services, and are particularly important in sequestering carbon as well as protecting inland habitats from inundation during storm surges.
The restoration of saltmarsh on farmed areas through **managed coastal realignment** represents an important option for future land-use change on the Norfolk Coast, particularly in the context of rising sea levels.

Saltmarshes and carbon finance

A UK **Saltmarsh Code for carbon finance** is currently under development, and is expected to operate in a similar fashion to the current Peatland[1] and Woodland[2] Codes.
Existing mature saltmarshes store and sequester large amounts of carbon (much like existing woodland), but are unlikely to qualify for carbon funding – rather, carbon finance will be limited to **additional** carbon sequestered through **saltmarsh creation / managed realignment** schemes. Managed realignment projects on the Norfolk Coast could potentially access emerging carbon markets in coming years, or alternatively seek support through government schemes such as the Landscape Recovery pilots.



PEATLAND CODE

Saltmarsh carbon sequestration rates

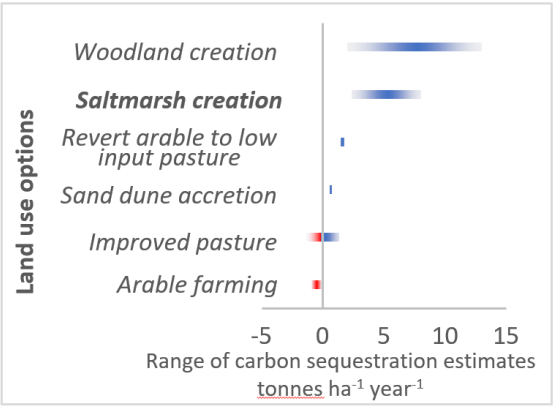
Carbon sequestration rates from re-creation of saltmarsh on farmland are **highly variable**, depending primarily on:

- net sediment accumulation rates, which depend on sediment content in tidal water and tend to be highest in lowest-lying areas
- the density of carbon in the accumulating sediment, which can be highly variable depending in part on the productivity of the system
- where the carbon originates from (only atmospheric carbon captured on-site 'counts' towards climate mitigation targets)
- the balance of net emissions from the developing saltmarsh, including production of methane, nitrous oxisde and other greenhouse gases

Direct measurements of these processes are likely to be needed in order to demonstrate carbon sequestration outcomes of projects seeking to access carbon finance markets. In particular, measurement of sediment accumulation rates (which can be done using Lidar imagery) and sampling to measure carbon density are likely to be essential.

Carbon capture and sequestration on saltmarsh occurs through CO2 being removed from the atmosphere on-site by plant growth. The majority of carbon is stored in the soil, when plant material is buried by the accumulation of new sediment. Creation of new saltmarsh on managed realignment sites can rapidly sequester large amounts of carbon, particularly if sediment accumulates quickly.

On average, **measured sequestration rates from UK saltmarsh schemes** are comparable to rates from woodland creation schemes (assuming mixed broadleaved natives, 30 year timeframe) :



Sources : NERR094 Carbon Storage and Sequestration by Habitat (2021), Burrows et al. (2014), Beaumont et al. (2014)

Biotope importance | Major habitat types | Saltmarsh | Sandy beach | Brackish features

[1]https://www.forestcarbon.co.uk/certification/the-peatland-code
[2]https://www.woodlandcarboncode.org.uk/

Sandy beach habitats and saline pools

Sandy beaches make a considerable contribution to the important plant and invertebrate biodiversity of inter-tidal areas at a landscape scale, including supporting some 26 localised species and 6 species with conservation status. These species occur both on the open sandy substrates themselves and on tidal debris of the strand line. Beach strandline habitats in particular support a relatively high proportion of the English fauna associated with this feature.

Sandy beaches come under considerable pressure from human visitors, posing a significant risk to nesting birds in particular in these habitats. Managing access to key areas by visitors and dogs is therefore important to avoid negative impacts on species of shoreline nesting birds (particularly Oystercatcher, Ringed Plover and Little Tern).

	% of possible species	Conservation status species	Localised species
Strand line	**45%**	2	**17**
Substrate	33%	**4**	9

Saline pools are another feature of the Norfolk Coast, primarily found on the landward side of shingle areas. Hypersaline pools are distinct from brackish pools as they have a salt content similar to or even higher than sea water (whereas brackish water has a lower salt content), and are typically formed in deeper depressions that are flooded infrequently by the sea that do not get flushed by fresh water.

They support relatively few species given their extreme conditions, but these include important invertebrates including the highly-localised **Starlet Sea Anemone *Nematostella vectensis*** (Section 41 Priority species). These saline pools may at risk from sea level rise and associated changes in coastal dynamics (including movements of shingle, sand and sediment). Creation of new hypersaline pools in suitable areas through mechanical scraping may be possible in the event that important sites become threatened.

Starlet Sea Anemone
© Smithsonian Environmental Research Centre

Beach strand line tidal litter
© R Rosser

Ethelcus verrucatus, a red-listed strand line species, photo © Udo

Sandy beach, Holkham gap
© Nigel Stickells

Biotope importance | Major habitat types | Saltmarsh | Sandy beach | Brackish features

Brackish habitats

Brackish habitats vary in their salinity and stability. The best examples within the Norfolk Coast study area (in terms of % representation of English species associated with these features) are areas with fresh-water seepages, where **brackish pools are regularly flushed by fresh water**. Larger numbers of priority species are found in **well-vegetated brackish pool margins**, as the overall national species pool associated with these features is larger. Brackish dune slacks also contain priority species.

% of possible species	Conservation status species	Localised species	
75%	4	1	Fresh-water seepages
56%	3	2	Dune slacks (Brackish)
52%	5	4	Well-vegetated margins
31%	1	1	Sparsely-vegetated margins

Sparsely-vegetated margins of brackish pools contain fewer priority species and are poorer examples of this national assemblage compared to other brackish guilds, but still support some priority species and thus remain a key component of the coastal habitat mosaic.

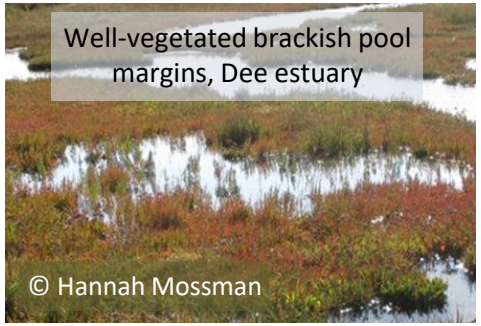
Some of the factors that contribute to high biodiversity value of the Norfolk Coast saltmarsh habitats are also likely to contribute to the high value of these brackish habitats – particularly in saltmarshes that are unconstrained by landward sea walls and transition gradually to higher landward habitats.

Furthermore some of these species may also be supported in ditches within the fresh water marshes where brackish water has seeped under defences or inundated.

Management options:

- Where possible, brackish habitats could be managed to feature a range of physically disturbed (sparsely vegetated) and undisturbed margin features.
- Existing brackish features may become more saline as sea level rise causes more frequent saltwater incursion, though new brackish features may also emerge within landward habitats.


Brackish dune slack, Winterton
© Wendy North


Well-vegetated brackish pool margins, Dee estuary
© Hannah Mossman


Saline features at Cley Marshes
© Paul Dolman

Biotope importance | Major habitat types | Saltmarsh | Sandy beach | Brackish features

Bog and mire

Relatively small areas of the NNC area contain these acidic wetland conditions, therefore we cannot use these metrics to compare their quality to the other biotopes which cover much larger areas. Taken independently of the other results, acidic bogs and mires contain a significant amount of priority species across their different microhabitats and on sites where the conditions (i.e. substrate and water chemistry) support them they are without doubt very important sites for biodiversity.

% of possible species	Conservation status species	Localised species	
27%	12	1	Shallow freshwater pond
24%	9	0	Sphagnum/moss lawn
41%	5	3	Deep litter
29%	11	1	Aquatic, well-vegetated
25%	7	2	Wet/damp peat
43%	6	0	Aquatic sparsely-vegetated
29%	13	0	Wetland vegetation

Dersingham Bog NNR, photo: WE Lee

Valley mire, Dersingham Bog NNR photo: Tony Bennet

Sphagnum lawn, photo: Agnes Monkelbaan

Bog and mire

Dung and carrion

Dung and Carrion

A significant number of priority species use dung and carrion resources, and are not necessarily tied to a particular biotope or habitat but may be found sporadically where the appropriate food sources are available. Important sources of carrion on the Norfolk coast may include seal carcasses as well as birds and rabbits.

Dinothenarus pubescens, a localised dung-feeding species
photo © UR Schmidt

% of possible species	Conservation status species	Localised species	
63%	2	3	Tall Sward, Carrion
64%	0	4	Tall Sward, Dung
26%	2	1	Short Sward, Carrion
33%	0	0	Short Sward, Dung

Important Note: These numbers of priority species are very likely an underestimate as the rarity status of some important beetle groups are in the process of being updated. Of the 111 invertebrate species we have associated with Dung and/or Carrion in the NNC area, 20 have a localisation score of 5-10% which is within the higher range of many priority species.

Management options: Most anthelminthic drugs and livestock treatments can have lasting negative effects on invertebrates that use dung from treated animals. There may be significant benefits to biodiversity by reducing such treatments (e.g. by targeting treatments using worm egg-counts), wherever possible dosing animals only in winter quarters, managing worm burdens to reduce drug resistance, and careful selection of new stock.

Bog and mire
Dung and carrion

Methods summary: How does 'biodiversity auditing' work?

Biodiversity Audits
Species data
Management Guilds
Glossary of terms

The Biodiversity Audit is a framework to guide conservation management developed by researchers at the University of East Anglia. The process involves collating already-available species records – each with the place and date where a particular species was observed – to develop a comprehensive list of the many thousands of species that occur in that region. Cross-referencing this with information on species conservation status allows us to identify the regional and national significance of each species and thus which should be considered priorities for conservation.

The Biodiversity Audit then synthesises available information on the ecological, habitat and management needs of these species, using species attributes available in public databases, supplemented by consulting expert taxonomists. Auditing serves to input, collate, analyse and synthesise this information in a form that is easy for managers to interpret and apply. Crucially, the audit process also integrates this evidence with the local expert knowledge of naturalists and land managers via a series of workshops, allowing outputs to be refined and information gaps to be identified. Further explanation of the methodology is available in a technical annex to this report.

The aim is to provide clear guidance for management that can sustain, support and enhance the full complement of priority species, to secure the biodiversity and natural heritage for the future.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The biodiversity audit approach challenges regional priorities and identifies a mismatch in conservation

Paul M. Dolman*, Christopher J. Panter and Hannah L. Mossman

School of Environmental Sciences, University of East Anglia, Norwich, UK

Species data: collating and validating the Norfolk coast species list

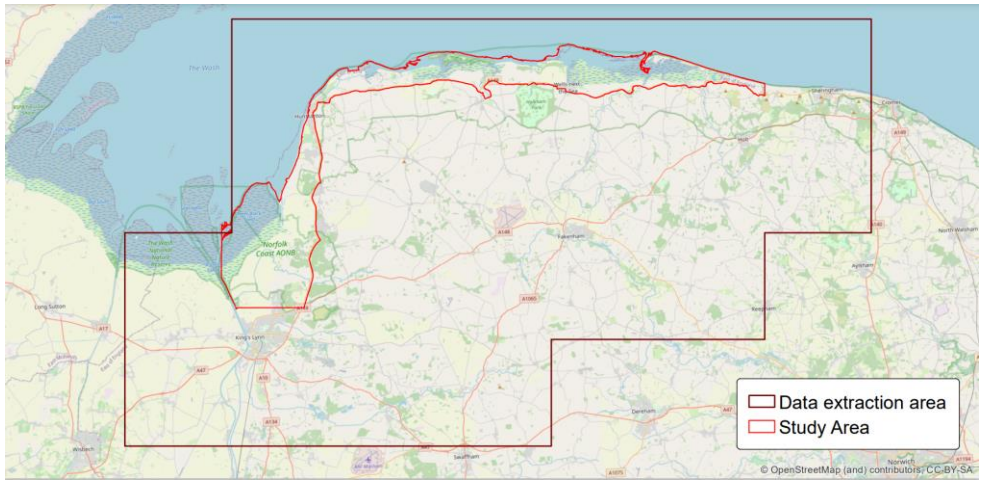
Data acquisition and validation workflow. The study area was defined as the low-lying coastal strip from Kings Lynn to Kelling Hard. Species records were obtained from a wide range of databases including NBIS, NBN, i-record, national recording societies, NGOs and individual recorders (see acknowledgements for list of sources).

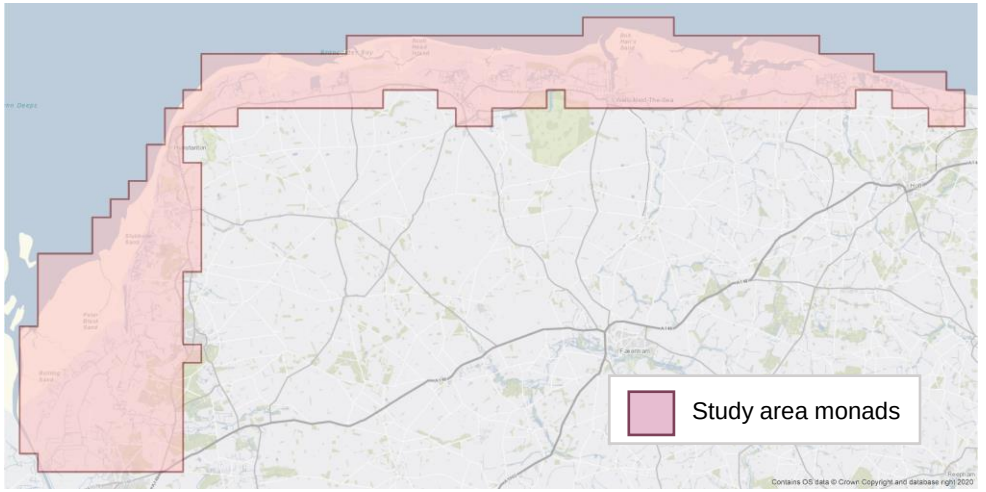
Biological records (each comprising species name, location, date) were accepted at hectad (10 km x10 km) or finer resolution, and records at monad (1x1 km^2) or finer resolution were extracted when within any monad that intersected the study area. Coarser resolution records (i.e. hectad or tetrad, 2x2 km^2) were extracted if a study area monad occurred within them. All species were validated with a local natural history expert (usually the county recorder) and the spatial resolution of the most precise record was supplied to help judge whether species actually occur within the study area.

Only records from 1980 or later were considered in analysis.

Conservation status was determined from the JNCC master list, considering Global, Great Britain and English Redlists (IUCN nationally Near Threatened, Vulnerable, Endangered or Critically Endangered, RDB lists, nationally rare or scarce, S41, Spider Amberlist). In addition to birds, reptiles and amphibians, conservation status has been reviewed across a very wide range of other taxonomic groups (including vascular plants, bryophytes, spiders, millipedes, centipedes, aquatic hemiptera, shieldbugs, many beetle families, grasshoppers and crickets, dragonflies and damselflies, butterflies, mayflies, stoneflies, some Diptera families incl. hoverflies, and non-marine molluscs). Groups not yet similarly assessed for their national conservation status include fungi, lichens, earthworms, nematodes and aquatic worms, marine molluscs, and parasitic wasps [1].

To allow localised species to be identified, extent of each species national distribution (range) as number of hectads with records from 1980 or later was determined using a custom data summary from NBN Gateway.





Biodiversity Audits | Species data | Management Guilds | Glossary of terms

[1] Webb & Brown (2016) The conservation status of British invertebrates. *British Wildlife*, August 2016, 410-421.

Species data: analysis in relation to comparator sites

Comparator analysis.

For each major biotope, a set of the most important and representative sites in England or Wales that support similar ecosystems was identified in consultation with national biodiversity experts at Natural England.

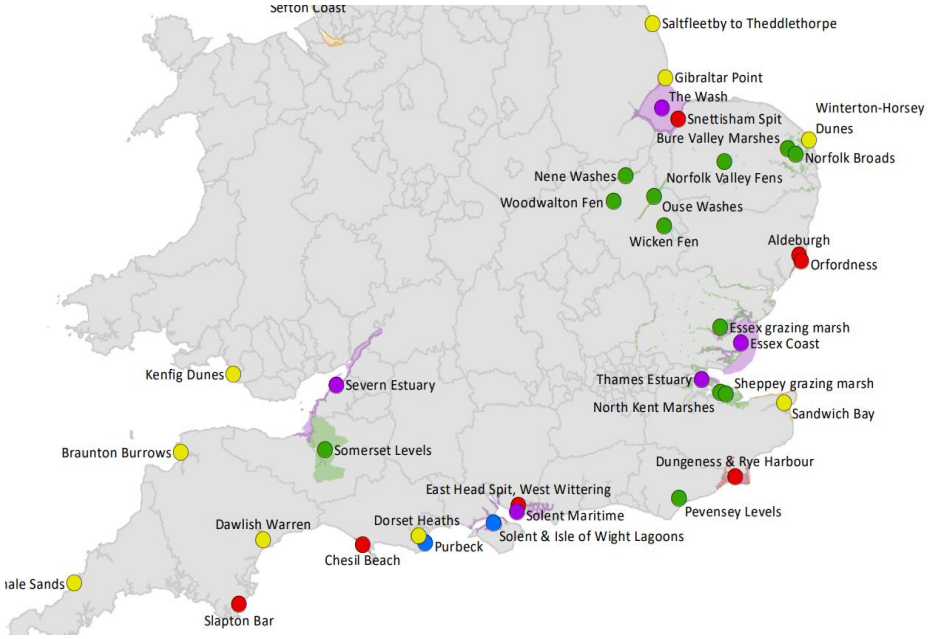
Biological records where extracted identically for the Norfolk Coast study area and for each comparator site at hectad (10 km x10 km) or finer resolution from the NBN Gateway.

Records were spatially refined to their respective sites using the same method used for the species list in the main analysis described under 'Data acquisition' (see page 43).

With a separate model for each biotope-association, numbers of priority invertebrate species (with a conservation status) were compared between comparator sites by a GLMM with negative binomial error, testing the fixed effect of site (relative to Norfolk coast, set as the intercept), incorporating nested random effects for taxon group (N = 10, taxon groups: Aranae, Coleoptera, Decapoda, Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Odonata, Lepidoptera, Trichoptera) and microhabitat (4 for dunes, 6 for grazing marsh and 7 for saltmarsh and brackish) to smooth out differences between the numbers of priority species of each taxon group associated with each microhabitat across the sites. As well as using the most appropriate comparison (comparing like with like) this may dilute effects of sampling biases between taxon groups at different sites.

In practice, this means the model asks: *Across the range of habitats in this biotope does this comparator site have fewer priority invertebrate species across the taxonomic groups, relative to the same microhabitat and taxon group in the North Norfolk Coastal area?*

The scale of the plots is non-linear as these use incidence rate ratios to represent the estimate for each site. For example a site that had an estimate of 0.5 would mean that, relative to a similar microhabitat on the North Norfolk coast, you would typically expect to find half as many invertebrate species with conservation status from a given taxon group.



Biodiversity Audits
Species data
Management Guilds
Glossary of terms

Guilds: assigning species to habitats and management choices

Analysis of species ecological (and management) needs

- Major habitat associations of all plants and invertebrates were resolved to Biotope level.
- For finer management guilds within broad Biotopes, Pantheon species attributes for invertebrate species include habitat niches and resource. Earlier Biodiversity Audits of Breckland and the Fens also coded landuse/habitat types and ecological processes – including distinguishing grazing from physical disturbance – helping link species' autecology to their management requirements.
- Using Pantheon it was possible to associate invertebrate species of **grazing marshes** and **wetland** complexes in relation to separate hydrological gradients of wetness (from damp, through saturated, to tall swamp and open water), and grazing intensity (short or tall swards, sparse or dense aquatic vegetation), by combining Pantheon resources from its 'open-habitats' and 'wetland' biotopes.
- To guild important plants, management guilds from previous Biodiversity Audits[1] were matched to the selected Pantheon resources and the plants of those guilds associated with the resources.
- Important plant species not included in previously audited bioregions (n = 158) were placed into one or more guilds based on the 'Ecology' statements in the Online Atlas of the British and Irish Flora.
- For **grazing marshes** and **wetland** complexes the relative suitability of drainage ditches (or clear water conditions), pools, scrapes (often with greater turbidity) or dune slacks for different species is not known; though a subset of species restricted to dune slacks were identified by participants,
- Better understanding of where in **coastal wetland complexes** particular priority species occur could help target interventions.
- For invertebrates associated with dry-open terrestrial habitat, including **sand dunes and coastal heath**, Pantheon coded invertebrate species on a composite disturbance gradient (from short/bare, to long/scrub) but did not separate grazing from ground disturbance. Pantheon also coded species associations with exposed sand, but did not resolve yellow (mobile) from grey (stabilised lichen-rich) dune, or associations with dune, dry lowland heathland or chalk grassland. An earlier Breckland audit showed many coastal species (including those associated with shingle and grey dune) also occur in human-disturbed dry open habitats including lowland heath [2], gravel pits or sand pits. Management guidance for these species is therefore applicable to both **sand dunes and coastal heath** parts of the landscape.
- For invertebrates of **saltmarsh and brackish** Pantheon separates these from terrestrial habitats but does not categorise them with respect to saltmarsh zonation or management.

Pantheon classifies species with or without conservation status. Our guilding of plants (and that of previous biodiversity audits) was restricted to just those species with conservation status or localised species – this is why our '% of possible species' metric uses only invertebrate species, as calculation of this metric requires information on the habitat requirements of all English species for a given taxonomic group.

Future recommendation:

Spatial targeting of interventions within the coastal area and extending audits to other bioregions would be strengthened by: greater resolution of Pantheon attributes for physical management of dry habitats; a combined invertebrate and plant management guild classification; and better resolution of species associations with wetland landscape elements.

Biodiversity Audits | Species data | Management Guilds | Glossary of terms

[1] Dolman, et al. (2010). *Securing Biodiversity in Breckland: Guidance for Conservation and Research. First Report of the Breckland Biodiversity Audit*. UEA, Norwich; Mossman, et al. (2012). *Fens Biodiversity Audit: Part 1 & 2 - Methodology and Results*. UEA, Norwich.

[2] Heathland occurs within or adjacent to the study area at: Grimston Warren; Roydon Common SSSI; Dersingham Bog SSSI; Snettisham Carstone Quarry SSSI; Salthouse Heath; Kelling Heath SSSI; chalk grassland occurs at Wells Chalk Pit SSSI; Cockthorpe Common, Stiffkey SSSI;

Glossary

Autecology: The study of the traits and characteristic of a specific taxon

Biotope: A group of similar habitats that are formed, structured and maintained by common processes.

Conservation status: species classified as being near threatened or threatened.

Damp [soils]: Soils that are moist but not so wet that water is free to pool at the surface, except under pressure (such as underfoot).

Dunes, Shingle and Heath: A biotope in our analysis, all are open (unwooded) dry terrestrial habitats that are formed, structured and maintained by disturbance, typically deposition and erosion of wind-blown sand, heavy grazing and `nutrient poor conditions.

Dune slack: A depression formed where wind erosion has stripped part of a sand dune all the way down to the water table, creating pools or damp conditions.

Fore dune: See **Yellow dune**

Grazing marsh and freshwater habitats: A biotope in our analysis, all habitats that that are formed, structured and maintained by the presence of fresh water

Grey dune: Sand dunes that are stabilised and more vegetated, usually behind the seaward fore dunes, and often covered in short turf rich in lichens (hence the 'grey') .

Guild: A group of species that share a given trait or characteristic

Habitat: A component of a biotope (e.g. standing water).

Heterogenous: A mix of opposing or different conditions

Localised species: Plant or invertebrate species for which we estimate that the study area constitutes 10% or more of their GB range.

Management guild: The species associated with the fine scale conditions created when a habitat is managed in a certain way (e.g. densely vegetated pool margins).

Mosaic: an arrangement of different habitat conditions so that contrasting patches are arranged next to each other (juxtaposed) in a mixed or random pattern. Can be important to invertebrates with complex requirements.

Opportunity cost: Benefits that otherwise would be achieved, but that are forgone due to a given management choice.

[Percentage] Possible species: The proportion of all English invertebrate species in a given guild that are found in the study area.

Priority species: important species that either have a **Conservation status** or are **Localised species,** not to be confused with S41 Priority Species, a specific designation.

Saltmarsh and Brackish: A biotope in our analysis, all intertidal habitats that are formed, structured and maintained by the presence of saline water.

Saturated [soils]: Soils that are so wet that water is free to pool at the surface.

Standing water: A habitat in our analysis within the 'Grazing marsh and freshwater habitats' biotope. Fresh water that is not flowing; e.g.: pools, ponds, scrapes, still ditches.

Strand line: Material and litter that is deposited by the tide, can also be buried under silt or sand, depending on the substrate.

Succession: A pattern of ecological change where more and different vegetation takes hold resulting in fewer resources for what was there before (the early-successional community).

Running water: A habitat in our analysis within the 'Grazing marsh and freshwater habitats' biotope. Fresh water that is flowing; e.g.: rivers, spring lines, seepages, flowing ditches.

Yellow dune: Pioneer and establishing dunes on the seaward side, that are typically characterised by bare sand and Marram Grass (*Ammophila arenaria*) and are the source of wind blown sand to the rest of the dune system. Can gradually stabilise and develop into **Grey dune**.

Biodiversity Audits | Species data | Management Guilds | Glossary of terms

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