

## Supplement S9 to Chapter 9: Ecosystem Services of Sand Dunes and Salt Marshes

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Sand dunes provide important ecosystem services for a large sector of the European population. The ecosystem services provided by sand dunes are far greater than their small area implies, both in terms of the number of people that benefit from them, and their economic value. Ecosystem services provided by sand dunes were discussed by Everard et al. (2010) (see Table S1) and the state and trends in these were discussed in detail from a UK perspective in the UK National Ecosystem Assessment (Jones et al. 2011).

Apart from abiotic and diversity targets, ecosystem goods and services may play a role in setting targets for salt-marsh restoration. Some of the goods and services that salt marshes provide are considered of 'high' importance by an expert panel (Jones et al. 2011; see Table S2). Salt marshes were estimated to provide more economic value per unit area than most other ecosystems if tourism, carbon storage and coastal defence were combined. An attempt has also been made to indicate the extent to which these services can be regained along with salt-marsh restoration (Jones et al. 2011).

**Table S9.1** Ecosystem services provided by sand dunes, adapted from Everard et al. (2010). Importance score: 1 (low), 2 (medium), 3 (high) (a score in brackets denotes historical importance).

Ecosystem services	Score	Comments
<b>Provisioning Services</b>		
Fresh water		
Drinking water and Irrigation	3	Drinking water abstraction is important in the Netherlands, Germany and Denmark. There is some small-scale abstraction for golf course watering
Food		
Meat, including Rare breed cattle	(2) 1	Historically important in north west Europe. Market in rare breed cattle is a potential growth area
Wild food	1	Some wild food harvesting (mushrooms, berries etc.)
(Rabbit farming, some crops)	(3)	Historically very important
Fibre and fuel		
Timber	2	Commercial plantation forestry occurs on some dunes in Europe (at present largely uneconomic)
Wool	1	Agricultural sheep grazing on some sites, but stock are also used for conservation grazing
Grass/reeds	(2)	Marram grass (and possibly <i>Phragmites</i> ) was historically important for mats, basket-weaving and thatching
Genetic resources		
Biochemicals, natural medicines, pharmaceuticals	1	Potentially high due to characteristic biodiversity. Some species under research for biochemical/pharmaceutical uses e.g. sea holly <i>Eryngium maritimum</i>
Reservoir of genetic diversity	1	Potentially high due to characteristic biodiversity of wild species; conservation grazing maintains stock of agricultural rare breeds
Mineral extraction	1 (2)	Sand extraction for use in construction and industry continues at small scale but was historically much more important
Landscape suitable for industrial and other use	2	Several sites used as landfill for gas/oil pipelines; coastal locations for power stations; Locally important for military use including firing ranges, vehicle manoeuvres etc

**Regulating Services**

Natural hazard regulation (i.e. storm protection)	3	Dunes have a significant role in buffering storms and other extreme natural events, providing a major coastal defence
Water purification of drinking water and groundwater	2	River water is infiltrated into dune systems for purification. Dunes are also likely to purify groundwater, protecting the marine environment, but this is not studied. ( <i>Research gap</i> )
Climate regulation	1	Carbon accumulation rate is high as this is an early successional habitat although overall dune areas are low
Air quality regulation	1	Canopy roughness of low-level grassland and scrub may be significant in particulate fallout and dry gaseous pollutant deposition
Pollination	1	Dunes harbour many natural pollinators, but their specificity for crop pollination has not been studied. Importance depends on patterns of coastal land use. ( <i>Research gap</i> )
Pest regulation	1	Dunes are likely to harbour natural predators of crop and stock pests, though this is not well studied. Importance depends on patterns of coastal land use. ( <i>Research gap</i> )

**Cultural Services**

Recreation and tourism	3	Sand dunes are a major tourism and leisure destination. Amenity uses include walking, cycling, horse riding, golf
Aesthetic value	2	Evidence of the popularity of sand dunes in photos/adverts shows the popularity of sand dunes with the public
Social relations	2	A focus for local nature groups, photographers, bird watchers, etc
Cultural heritage	2	Sand dunes provide 'wild' landscapes but also carry historical fears about sand inundating fields and villages
Inspiration of art, folklore, architecture, etc	1	Poems inspired by dunes include works by Robert Frost (1874–1963), Carl Sandburg (1878–1967). Paintings by many Dutch artists feature dune landscapes
Educational resource	2	Coastal sand dunes provide an important educational resource, for illustrating natural processes, ecological theory, biodiversity, and competing land management pressures
Spiritual and religious value	?	Unknown ( <i>Research gap</i> )

**Climate change impacts on ecosystem services of sand dunes and saltmarsh**

Domestic tourism and recreation are predicted to increase under climate change in northern and temperate areas as warmer summers make domestic destinations more attractive, coupled with the climate in traditional Mediterranean destinations starting to exceed comfort thresholds (Hamilton et al. 2005). Coastal tourism in all North Sea countries is expected to benefit from this (Willms 2007; Coombes and Jones 2010; Verhofstede et al. 2011), despite possible declines in coastal water quality (Verhofstede et al. 2011) and narrowing of beaches due to sea-level rise (SLR) (Coombes and Jones 2010).

Coastal defence provided by sand dunes and saltmarsh will come under increasing pressure due to climate change. Increased wave heights, storm surges and SLR, coupled with observed steepening of beach profiles and a historical decline in sediment availability due to coastal protection mean less sediment is available to replenish erosion of beach sand. Larger dune systems will be able to accommodate losses due to coastal erosion, and to absorb coastal flooding if the foredunes are

breached during storms. However, narrower dune systems may not be able to cope with such events. Vertical accretion of saltmarsh is unlikely to keep pace with SLR, therefore its ability to dissipate wave energy will diminish. Coastal defence is considered in more detail in Chap. 18.

Water supply in coastal dunes is dependent on natural recharge from rainfall, and supplementary recharge from infiltrated river water. The likely effects of climate change on aquifer recharge are complex and to a large extent unknown. In the northern North Sea region, river runoff is predicted to increase due to winter rainfall increasing by up to 50%, with smaller declines in summer rainfall (SOU 2007; Verhofstede et al. 2011; DiPOL 2012). It is likely that recharge of dune aquifers will also increase. However, predictions for the southern North Sea region vary. Recharge of chalk aquifers in the UK is predicted to decline (Younger et al. 2002), with a decline of around 5% in river runoff predicted in the southeast UK by the 2080s (Alcamo et al. 2007), while predictions of recharge to dune aquifers in the Netherlands and Belgium vary from slight increases to slight decreases (Vandenbohede et al. 2008; Witte et al. 2012). On barrier islands, SLR may induce saltwater intrusion, and some islands such as Schouwen-Duiveland may need to increase their reliance on water pumped from the mainland (Verhofstede et al. 2011).

The quality of river water used to infiltrate into dunes for drinking water purposes may decline (Van Vliet and Zwolsman 2008) under reduced summer rainfall, leading to increased pre-treatment costs where the water purification function of dunes is used.

Rates of soil formation and therefore carbon sequestration in dune soils are higher with warmer temperatures (Jones et al. 2008). Thus carbon sequestration may increase on northern North Sea coasts, but may decrease on southern coasts if the soil moisture deficit in summer leads to slower plant growth and an increase in bare sand (Witte et al. 2012). However, coastal erosion due to SLR and storms will lead to a net loss of carbon sequestration potential in sand dune and saltmarsh habitats over time (Beaumont et al. 2014).

**Table S9.2** Goods and benefits provided by ecosystem services from (semi-)natural salt marshes (after UK National Ecosystem Assessment; <http://uknea.unept-wcmc.org/>) (Jones et al. 2011). Importance score: 1 (low), 2 (medium), 3 (high)

Ecosystem services	Score	Notes
<b>Provisioning Services</b>		
Crops, plants, livestock, fish, etc (wild and domesticated)	3	Meat: sheep/cattle/fish
	2	Wild food: <i>Salicornia</i> /other plants/fish/wildfowl
	1	Wool (sheep)
	2	Genetic resources of rare breeds, crops
Trees, standing vegetation and peat/other resources	1	Turf/peat cutting
	1	Military use
	1	Industrial use: pipeline landfall
Wild species diversity including microbes	3	High diversity, or rare/unique plants, animals and birds, insects
	3	Ecosystem-specific protected areas
<b>Regulating Services</b>		
Climate regulation	3	Carbon sequestration
Hazard regulation: vegetation and other habitats	3	Sea defence
	3	Preventing soil erosion
Waste breakdown and detoxification	3	Immobilisation of pollutants
	3	Nursery grounds for fish
Wild species diversity including microbes	3	Breeding, overwintering, feeding grounds for

		birds
Purification	?	Water filtration: groundwater, surface flow, seawater
<b>Cultural Services</b>		
Spiritual/religious + Cultural heritage and media	2	Sites of religious/cultural significance; World Heritage Sites; folklore; TV/Radio programmes and Films
Aesthetic/inspirational	2	Paintings, sculpture, books
Recreation/tourism	3	Many opportunities for recreation: including sunbathing, walking, camping, boating, fishing, birdwatching
Physical/mental health + Security and freedom	1	Opportunities for exercise, local meaningful space, wilderness, personal space
Education/ ecological knowledge	3	Resource for teaching, public information, scientific study
Cultural heritage	2	Salt marshes provide characteristic semi-natural (grazed) and man-made (sedimentation fields) landscapes but also carry historical fears about water inundating fields and villages, and feature the history of embankments

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