

Deelgebied/Culturele entiteit:

Wadden Sea

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1. Geology and geography

From a geological point of view the Wadden Sea is very young, dating from the latest geological period, the Quaternary. The sedimentary deposits are mainly sand and silt, as well as organic materials, that are modelled and remodelled every hour by the constant working of water and wind, of tides, drifts and currents. Shallows like the Wadden Sea develop as the result of interaction between a relative rise in sea-levels and a supply of sediment. The rise in sea-levels leads to increasing water-depths. However, the supply of sediment results in the expansion and heightening of sand- as well as mud-flats, both becoming larger and higher, thereby annulling the effects of sea-level rising.



Southern Wadden Sea

Large areas of stones forming reefs (derived from glacial ground moraine or till) to the northwest of the islands of Texel and Vlieland as well as to the northwest of Borkum and Juist (the Borkum Riff) are for a large part responsible for the location of the Wadden Sea. These are old Pleistocene remnants of the former mainland which have proved resistant to erosion by the sea. As such they act as the points of suspension for the coasts of the Southern Wadden Sea. The Texel reefs are responsible for the convex curved coast in the Dutch part of the Wadden area and the Borkum Riff is of similar importance for the East-Frisian coast. The Pleistocene heights of the Hohe Lieth near Cuxhaven both function as a suspension-point for the Elbe-marshes (e.g. Hadeln) to the east of it, as well as a point of resistance to erosion which facilitates the deposition of sediment on the Wurster Watt in front (west) of it.

When the supply of sediment is relatively large, a shallow water-basin like the Wadden Sea will, in the long term, warp under the weight of sand and mud, thus becoming dry land. This is the case along large segments of the coast, especially on the mainland where quite a few so-called *kwelders*, *grodens* or *hellers* (salt-marshes) exist. Former salt-marshes make up a large part of the mainland bordering the Wadden Sea and are in fact the result of comparable sedimentation in the past. They form a large alluvial plain of varying width, which, in the Dutch province of Fryslân extends up to 40 kilometres inward from the coast. Since the beginning of embankment about 1000 years ago most of them have been reclaimed from the sea. Today the mainland coast and the southern (viz. Wadden Sea) side of most of the Frisian Islands are protected by massive embankments. Along their seaward side these dikes are generally sheltered by a foreland consisting of salt-marshes. Along a substantial part of the mainland coast, until recently, land-reclamation was widely practised by using warping dams on tidal-flats and summer-dikes on the higher salt-marshes. Embanked salt-marshes, like those previously mentioned, are only inundated during storm-surges when the sea deposits a new layer of sediment. Every new storm brings in fresh sediment thereby slowly raising the salt-marshes. Parts of the Western Wadden Sea (e.g. near Harlingen, Delfzijl, Krummhörn) are characterized by a relatively small supply of sediment resulting in an absence of salt-marshes. More usually a decrease in sedimentation leads to a lowering in the height and numbers of sand- and mud-flats. In the end the Wadden Sea would be 'drowned' and transformed into a lagoon. The survival of the Wadden Sea therefore depends on a delicate balance between the rise of the sea-level and the availability of sediment.

The Wadden Sea is the main coastal feature on the German Bight, the part of the North Sea that is flanked by the northern coasts of the Netherlands and Lower Saxony and the western coasts of Denmark and Schleswig-Holstein. This shallow inland-sea, consisting of flats, gullies and tidal channels, is separated from the North Sea by a chain of mainly oblong-shaped barrier islands, the so-called Frisian Islands. In the area west of the river Elbe they are called *Waddeneilanden* (Wadden Sea Islands) in the Netherlands. East of the *Westerems* in Germany their name is *Ost-Friesische Inseln* (East-Frisian Islands). To the east of *Wangerooge* the chain of islands ends. Here, the estuaries of the rivers *Weser* and *Elbe*, Wadden Sea and North Sea more or less intermingle, from a geographical point of view at least. Nevertheless a few solitary islands like *Mellum*, *Hoher Knechtsand*, *Scharhörn/Neuwerk* together form an irregularly broken barrier. Each of these small islands have their respective, and sometimes, large flats (*Watten*) lying in their shadow, e.g. *Der Hohe Weg*, *Wurster Watt*, *Neuwerker Watt* etc. On the mainland the Wadden Sea is bordered by sea-marshes and heavy coastal defences like dikes and jetties protecting the harbours. The main ports and harbours of the Wadden Sea are *Den Helder*, *Den Oever*, *Harlingen*, *West-Terschelling*, *Lauwersoog*, *Eemshaven*, *Delfzijl*, *Emden*, *Greetsiel*, *Wilhelmshaven*, *Bremerhaven* and *Cuxhaven*. Inland on the Rivers *Weser* and *Elbe* respectively lie the main international German ports of *Bremen* and *Hamburg*.

Apart from the irregularity of the barrier separating the Wadden Sea from the North Sea, the Wadden Sea itself has a varying width. It ranges from just six kilometres between the East-Frisian Islands and the mainland, up to 40-50 kilometres wide where the coast is indented by large bays like the *Jadebusen* and the *Dollard*. Former bays like the *Zuyder Zee*, the *Middelzee*, the *Lauwerszee*, the *Fivelboezem*, the *Bucht von Sielmönken*, the *Harlebucht*, the *Maade-einbruch* and *Schwarzen Brack* have been shut off from the sea or were drained and reclaimed.

With its rather broad channels and a mean breadth of 40 kilometres, the western part of the Dutch Wadden Sea has the appearance of a real sea. Up until 1932, when the *Great Enclosure Dike* (*Afsluitdijk*) was completed, this part of the Wadden Sea belonged to the *Zuyder Zee*. That year the Dutch cabinet abolished the old name *Zuyder Zee*, replacing it at the same time by *IJsselmeer* (south of the *Afsluitdijk*) and *Wadden Sea*. Until then (in the

Netherlands at least) the Wadden Sea didn't formally exist on the sea charts. It was divided into the Zuyder Zee and the Friesche and Groninger Wadden, separated from each other by an imaginary line from the island of Ameland to Zwarte Haan on the mainland.



Northern Wadden Sea

The distribution of thick glacial deposits, which are found in the deeper waters to the west of the Wadden Sea Area, are integral to the development of the landscape and the settlement history of the coastal area of North Frisia. These deposits were eroded by the post-glacial transgression of the sea. The heterogeneous material drifted away and was re-deposited, creating either sand spits along the flanks of moraines or forming extensive accumulations of sediments in the hinterland. Hostile conditions prevailed in the Wadden Sea Area of North Frisia, especially during the centuries before the birth of Christ. To the west of today's offshore sandbanks, moraine ridges and sand spits derived from moraine material cut off large areas from marine influence and extensive reed swamps developed.

The Wadden Sea Area of Dithmarschen is characterized by deep tidal gullies and channels. Offshore sandbanks are also subject to constant morphological changes. The post-glacial landscape and settlement history, however, differs from that of North Frisia. Glacial melt water was discharged through the Elbe and Eider rivers during the last Ice Age and eroded the ground off the coast. The glacial surfaces off the coast of Dithmarschen thus lie about 10 m deeper than the glacial surfaces off the coast of North Frisia. In consequence the impact of the North Sea hits the coast much earlier. The sea could penetrate as far as the Geestrand and wash away the land, forming spits parallel to the coast. Without the shelter of glacial deposits to the west of the Geestrand no marshes and reed swamps developed. Settlement remains of the Roman Iron Age and Medieval Times show, however, the gradual reclamation of marsh, starting at the Geestrand and advancing to the west, the mainly sandy soils provide a stable base for the construction of protective sea dykes. Except for a small area near Büsum, none of this reclaimed land has returned to mudflat.

The peninsula of Skallingen, the islands of Fanø, Mandø and Romø and the sandbanks,

such as Peter Mejers Sand and Jordsand, protect the Danish Wadden Sea Area against the open sea. The islands are, as with the East Frisian Islands, young in geological terms and their surface level is comparatively low. As on the mainland coast, marshes have formed on the eastern sides of the islands, but in places such as Emmerlev Cliff the glacial moraine meets the Wadden Sea. Between the islands and sandbanks are the large tideways (Gezeitenströme) of Grådyb, Knudedyb, Juvre Dyb and the Lister Tief in the border zone to the Wadden Sea of Schleswig-Holstein. These are extensions of the estuaries of Kongeå, Ribe Å and Hvidå/Wiedau and thus form good east-west shipping routes. Navigation in north-south direction is made difficult by shoals and, since modern times, the causeway that connects Romø to the mainland, the majority of shipping follows the route west of the islands and sandbanks.

Present landscape

The Wadden Sea landscape is primarily a flat and open ensemble. The horizon is mainly determined by natural phenomena. Apart from the water as a primary element, it is the marine shallows (depending on the tides), islands and salt-marshes that strike the eye. In addition, human elements like towns and villages behind the dikes, the sea-defences themselves, farm-houses and local industrial elements, as well as new wind turbines appear on the horizon. The principal sounds of the Wadden Sea are produced by flowing water, the wind, birds and other animals, such as seals. Another quality of the Wadden Sea landscape is the experience of real darkness.

The length of the barrier-islands depends on the mean tidal amplitude. The smaller the tidal range, the longer the island. As a result the longest barrier-islands (Texel, Terschelling and Ameland) are found in the west. It is probable that within 20 years it seems likely that there will be new offshore sands.

On the north-western side of the islands lie the ebb deltas which offer protection against the North Sea. To prevent erosion many islands are strengthened and fixed by protective groins (Texel, Vlieland, Borkum, Baltrum), seawalls and groins (Norderney), stonewalls (Neuwerk) as well as sand-dikes (Terschelling, Ameland, Wangerooge).

Almost 90% of the sediment deposited on the tidal flats consists of predominantly rather coarse sandy material, whilst the remaining depositions are finer textured, muddy particles. The zones of sedimentation are threefold. The first zone is permanently submerged by the waters of the sea and it is intersected by channels which are connected to the tidal inlets. The second zone is the area between mean high water and mean low water. This area of flats and gullies form the proper Wadden. They are characterized by mussel-banks and sometimes by ships lying dry and waiting for the tide. In the Wadden Sea most of the islands have a slack-water area called wantij (Dutch) or Hohe (German). The Ameland wantij was used to build a dam from this island to the mainland (1871-1882).

The third zone lies more or less permanently above mean high water, and is only inundated during severe gales. It consists of salt-marshes drained by creeks and gullies, constituting a protective and nature-rich foreland. These marshes are sometimes protected by summer-banks and on the seaward side by brushwood embankments enclosing mud-flats that in themselves are divided and drained by ditches and furrows. The salt-marshes are often used as a pasture for sheep, young cattle and horses, whilst in some places round fresh water-places surrounded by earthen dikes can be used as a refuge.

At many places pumping-stations (by means of engines) or sluices (by using the tides) have been built in the sea-walls to discharge surplus water from the interior.

Hydrography

The prevailing winds come from the west, and the tidal wave moves from the same direction, that is to say from south-west to north-east. It is through the tidal inlets and estuaries that connect the waters of the Wadden Sea to those of the North Sea and through which flood-streams bring the bulk of the sediment into the Wadden Sea. These tidal streams form so-called inner or flood-tidal deltas, branching like trees into the tidal flats of the Wadden Sea. A

part of the sediment returns to the North Sea by means of the ebb-stream, thereby forming smaller outer or ebb-tidal deltas usually consisting of one or more main channels separated from each other by sandy shoals. The maximum depth of the inlet channels and the inlet are linearly related to the tidal prism, i.e. the volume of tidal water passing through the ebb channel. Floodwaters usually enter a tidal inlet front-wise and as such have a wider spread throughout the inlet. Flood waters also make use of the minor channels and even when the main ebb current is still flowing, the flood stream has already entered through these marginal channels.

The ebb-deltas usually lie at the western head of the barrier-islands and offer protection to the island. They have a tendency to move in an eastern direction. In historical times villages (West-Vlieland, Sier, Westerburen, Oosterburen and de Dampen) have been lost and islands have disappeared (Bant, Buise). This was partly a result of the eastern overturn of the outer deltas and also of the widening of these deltas as a result of changes to drainage in the 'hinterland'. That tidal inlets (and in consequence the barrier-islands) have a tendency to wander in an eastward direction, in accordance with the prevailing wind and tidal stream, has furthermore been proven by the presence of former inlets in the subsoil of Norderney and Schiermonnikoog. To prevent further erosion many islands have been strengthened and fixed by protective groins (Vlieland, Borkum, Baltrum), seawalls and groins (Norderney), stone-walls (Neuwerk, in fact the only hallig on this side of the Elbe) as well as sand-dikes (Terschelling, Ameland, Wangerooge). Islands that have a base of boulder clay like Texel and Borkum are more stable and less prone to shifting.

A constant shifting of channels and sands in the outer deltas make them extremely difficult to navigate. The outer shallows of the Frisian Islands, because of their shifting sands and their heavy ground-swell, are notorious as naval graveyards. In the Wadden Sea itself, although less violent, many ships have also been wrecked. In particular, the old sailing routes to Amsterdam through the Marsdiep and the Vlie and the roads of Texel and Vlieland are of interest to marine archaeologists. In the mouths of the Wezer and the Jade the lighthouses and other seamarks form particularly essential parts of the maritime cultural heritage. Neuwerk, Borkum, Wangerooge and Terschelling have the oldest light-towers in the region, the Grosse Leuchtturm at Neuwerk and the Brandaris lighthouse on the island of Terschelling are still actively used as light-towers. In the mouth of the Weser, the Hohe-Weg (1854) and Roter Sand (1885, the hall-mark of the German coastal area) lighthouses are fine examples of technological innovations in location as well as building methods (caissons) and used materials (iron tower on a concrete base). Similar innovations characterize the cast-iron light-towers on the Dutch islands of Ameland and Vlieland.

Tidal ranges

The tidal range increases from west to east as well as in estuaries and bays such as the Dollard and Jade. The funnel shape of these inland bays, as well as the much larger bay that is formed by the German Bight, cause an increase in tidal amplitudes. The smallest tidal range is found in the west (Den Helder 1.3 m, Harlingen 1.8 m), it increases while going eastward to up to 2.82 metres at Cuxhaven. The funnel effect causes even greater ranges at Bremerhaven (3.38 m) as well as far upstream the river Weser at the port of Bremen (3.11 m). Even Hamburg, lying about 100 kilometres inland, has a tidal range of 2.25 metres. Barrier islands only develop in places where the tidal ranges are between 1.5 and 3 metres. This explains why east of Wangerooge there are no barrier islands, but only sandbanks on which dunes are hardly able to develop, while the west coast of Holland in reverse forms a closed barrier. Moreover there is a significant correlation between the lengths of the barrier islands and the mean tidal amplitude, viz. the smaller the amplitude the longer the island. As a result the longest barrier islands (Texel, Terschelling, Ameland) are to be found in the west and the smallest in places where the difference between high water and ebb is at its biggest. The tides have their greatest velocities in the channels through the inlets between the islands, up to 1.8 metres per second. As a result of strong gales and storm surges tides can be raised up to 4 metres above mean high water!.



Sedimentation

Practically all the sediment transported into the Wadden Sea comes from the North Sea, where it is derived from the shore-face and the beaches and dunes of the Frisian islands and the North Holland coast. The characteristic sediment in the North Sea is a mainly blue-grey coloured, non-layered sandy mud. Almost 90% of the sediment deposited on the tidal-flats consists of predominantly sandy materials, whereas the remaining depositions are finer textured, muddy particles. The latter comes from other, more distant sources like the river Rhine, the English Channel and from deeper parts of the North Sea floor.

The zones of sedimentation as a rule lie parallel to the coast. The first zone is an area below mean low water which is permanently submerged. The channels connected to the tidal inlets belong to this zone. The second zone is the area between mean high water and mean low water. It is the area of flats and gullies and as such the proper Wadden. They are characterized by 'wad-worms' and mussel-banks. The third zone is above mean high water and consists of sea-marshes and their creeks and gullies.

In the vicinity of the islands it is fine sands that dominate. Wind and waves are responsible for the sedimentation of barriers, beaches and dunes, whereas clay and mud-particles are deposited in quieter areas. Every island has its windward, sea or sand-side characterized by often very broad and beautiful beaches and high dunes, opposed to a sheltered lee-side, dominated by partially embanked, tidal marshes. Former tidal marshes also dominate the mainland. They have been reclaimed by dikes into polders, following the embankment of the area from about 1000 AD onwards. Outside these mainland dikes there are numerous salt marshes (kwelders, groden) along the coast. Together they constitute a protective and nature-rich foreland that stretches from the 'kwelders' of Zwarte Haan in Friesland in the west to the groden on the Wurster and Sahlenburger Watt in the east. In some of the salt-marshes, experiments are being undertaken in restoring the interaction between salt and fresh water by the so-called outbanking of summer-polders (e.g. Noorderleech and Polder Breebaart).

Salt marshes are also found on the islands. They have been partly embanked as polders – the Borkum Außenweide is protected by a summer-dike ? but often lie open to the sea, such

as the Groede (Terschelling), the Zoute Weide (Ameland), Oosterkwelder (Schiermonnikoog), the Groen of Spiekeroog, the Außengroden of Wangerooge. The Wadden Sea Area of North Frisia is a place of constant morphological change, which equally affects offshore sandbanks, mudflats, tidal gullies and channels. Sand is carried away eastwards by the constant onslaught of the North Sea on the western flanks of the offshore sandbanks Süderoogsand, Norderoogsand and Japsand. The sand deposits move across the adjacent mudflats in the east, which reappear on the western side and are then washed away by the surf. Consequently the offshore sandbanks shift gradually towards the islands and Hallig islands resulting in the increasing loss of tidal mudflats. The mud substratum of the marsh islands and Hallig islands, too, is constantly transformed by the sea. Remains of settlements, commonly known as “culture traces” (Kulturspuren), destroyed by disastrous flood in Medieval or Early Modern Times, are uncovered by extensive erosion and bear witness to the morphological changes. The cultural traces are either destroyed by erosion or are buried by younger deposits. Morphological changes in the tidal channels are not as easy to detect. An increased depth, however, indicates further erosion and cultural traces appearing on the banks show the widening or shifting of a tidal channel. The influence of the North Sea on the erosion and sedimentation processes in the Wadden Sea Area of Dithmarschen was probably basically the same as in North Frisia. The offshore sandbanks, however, suffered a different fate. Some were completely eaten away by the sea (Tötel), whilst others became part of the mainland by empoldering (Dieksand) or they are still exposed to tide and winds and consequently shift towards the mainland. Decreased influx of sediments or the crossing of a deep tidal gully can mean the end of a sandbank (Tertius). It is uncertain what the destiny of others (Trischen, Linnen and Blauort) will be. From observations over the last 20 years it seems likely that there will be new offshore sands in the future.



Slack-water areas

In the Wadden Sea most of the islands have a slack-water area (wantij, Hohe) east of the middle of the island at two-thirds of its length from the west. In the inlets between the islands, the times at which the tidal streams begin, becomes later from west to east. The flood

stream, after passing the islands, spreads out and runs in all directions. The eastward and westward streams from the inlets on both sides of an island meet behind that island at the so-called wantij (Dutch) of Hohe (German). An area of slack-water and eddies, creates quiet depository qualities in which silt rather than sand is deposited. Falling tides run first across the sands and as the tide falls through the channels.

As a rule sand-flats or sand-banks formed there rise higher than other flats in their vicinity. The 'wantij' banks extend from most of the islands in a south-easterly direction to the mainland coast. In the years 1871-1882 the slack-water area of Ameland was used to build a dam from this island to the mainland. Part of the dam is still in use as the landing-stage for the ferry to Ameland. In the shadow of some of the barrier-islands as well as behind and protected by a shallow shoreface there are sand-islands in various stages of development like Memmert (near Juist) and Lütje Horn (Borkum), Richel (Vlieland), Engelsmanplaat, Rottumeroog and Rottumerplaat and Simonszand.

2. Landscape and settlement history

The Wadden Sea is the most dynamic natural landscape of Western Europe. The sea, its islands and coastal surroundings together form an ever shifting 'monument' of topographical changes. As a consequence, the history of the Wadden Sea is a fine example of man coping with his environment, of trial and error as well as of expansion and contraction. Socio-economically it is a good example of a society based both on agriculture and maritime activities (sailing, fishing, salvage and reclamation). Large parts of what is now land were sea about 1000 years ago and vice versa. The Marne-estuary (south of Harlingen), the Middelsea-inlet with It Bildt, the inlets and former estuaries of rivers like the Lauwers, the Hunze and the Fivel were all part of the Wadden Sea and have since been reclaimed. The same goes for the bays and gulfs of Campen, Sielmönken, Harle and Maade in East-Friesland and Oldenburg (both in Lower Saxony).

Prehistoric and Medieval Times

At the end of the last Ice Age the Wadden Sea area was dryland, with the coast located to the west of the present Dogger Bank. Finds recovered during dredging or fishing in this marine environment have established that the area hosted large herds of animals and bands of hunter-gatherers. However, as sea-levels rose the inhabitants must have retreated back to the current shoreline. There are undoubtedly Palaeolithic and Mesolithic sites under the present Wadden Sea, buried beneath many metres of sediment.

There is more information for the Neolithic period. For example, many finds have been recovered from the Wadden Sea Area between the Eiderstedt peninsula and the island of Föhr, including late Neolithic and early Bronze Age flint daggers and flint sickles. These, prove the presence of people in this area in the late 3rd and early 2nd millennium BC, and probably even human settlement. Some undisturbed sites have also provided information about the surface level of the marsh 4000 years ago. Middle Neolithic finds are often recovered on the coasts of Fanø. The finds must originate from submerged hunting camps and are washed ashore. The most outstanding find is a stylised bear made of amber. Today the level is 1.50 m below sea level (NN), but the spatially varying subsidence of glacial sediments must be taken into account. There are no artefacts from the following periods, the late Bronze Age and the pre-Roman Iron Age, so far from the northern coastal marshes. Finds of the 2nd to 5th century AD have been recovered from an area between the Japsand west of the Hallig island of Hooge and the island of Pellworm demonstrating that by the 2nd century A. D. people had returned to the southern parts of the Wadden Sea Area of North Frisia. In Roman times a large part of the Wadden Sea south of an imaginary line between Texel and Zurich (Friesland) were in fact raised bogs fringed by a rather narrow belt of marshland.

There appears to have been a general abandonment of settlements across the region during the late Roman Iron Age and the Migration period, probably due to rising sea-levels and storm-tides in the 4th century. Settlement recommences in the 7th or 8th centuries, often in

areas that had been previously favoured as settlements sites in the Roman Iron Age. However, these settlements were always vulnerable to storm-tides, of which the most famous and best recorded is probably the Grote Mandränke or 'Great Drowning' of 1362 which devastated the entire Wadden Sea region, submerging villages and islands and re-modelling the entire coastline.

From the 12th century onwards the sea, partly because of a more frequent storms, penetrated into this southern Wadden Sea area. This led to a decrease in the pressure on other areas, as a result of which the estuaries of the Marne and Middelzee were reclaimed. Higher storm frequencies, overdue maintenance, followed by the breaking through of dikes and the narrow marshy belts alongside the river Ems lead to the flooding of the subsided raised bogs in the hinterland. Scores of villages disappeared in embayments like the Dollard and the Jade. The Sehestedter Außendeichmoor or Schwimmende Moor is the only remaining example of a high moor bordering the Wadden Sea. On the contrary the development of large embayments like the Dollard and the Jade have made possible the gradual sedimentation and reclamation of coastal indentations elsewhere along the coast of Lower Saxony like the Harle-gulf and Maade-gulf.

There are quite a few islands that over the centuries have appeared on, or disappeared from, the map. In the Dutch part of the Wadden Sea the islands and sand-flats like Bosch, Heffesand, Corensant have all disappeared, whereas islands like Griend, Simonszand and Rottum(eroog) have shifted and became much smaller and new islands and flats such as Boschplaat, Engelsmanplaat or Richel evolved.



In Lower Saxony it was Lütje Hörn and Memmert near Borkum and Juist that appeared on the map as sandflats slowly evolving into dune-islands. On the other hand Bant, a hallig and Buise disappeared. The isle of Osterende (lying opposite and east of Buise) was renamed Norder neye Ooge (literally the new island of the neighbouring town of Norden) and as such was the precursor of Norderney.

In contrast with the Wadden Sea north of the river Elbe, the Western Wadden Sea has hardly any halligen. In fact only Neuwerk can be classified as such. Halligen are flat islands consisting of marshes that are only flooded during storm-tides. Griend, Bant near the

Lauwers and Bant on the Juister Watt, as well as Corenzand and Heffezand on the Groningen Wad were in fact halligen too. As a rule halligen evolve inside of the barrier islands. The study of borehole data has enabled the position of former halligen and other islands, as well as old coastlines in general, to be established.

It is not only through geological and archaeological exploration that the presence of former islands and coastlines can be proved. Near the surface, traces of occupation and of drowned fields and ditches have been discovered near the Weser and in the Jadebusen. On the North Sea beaches and sometimes in the fore-dunes as well (e.g. Borkum, Baltrum, Langeoog and Vlieland) traces of past cultivation are sometimes visible after gales or at low water spring.

The same goes for the western beaches of Ameland, Juist and Schiermonnikoog where traces of old villages (e.g. Sier, Billdorf and Westerburen) became or are still visible through remnants of furrows, ditches and wells, or by means of bricks, tiles and shards.

Elsewhere, e.g. south and immediately north of Harlingen, west of Moddergat, in the Westermarsch, between Bensersiel and Neuharlingersiel, the direction of the land-parcels on the mainland makes it clear that old agricultural land was lost to the sea.

As a remnant of a partly drowned landscape, archaeological traces of former settlements can be found or are historically documented throughout the Wadden Sea. Visible fragments of human occupation like the remnants of drowned villages, houses and farms may be found in the Jadebusen, but also off the mainland coast near Neuharlingersiel (Otzum, Ostbendum), off the Westermarsch (Itzendorf) and off Land Wursten (Rintzeln and Reminzeln).

Other remains, although mostly washed away or submerged, may be assumed elsewhere, especially off Texel and Wieringen (Balgzand), near the small island of Griend, off the north-coast of Fryslân (villages like Biniathorp and Dikesherne are historically documented near Harlingen) and most of all in the Dollard. Reclamation has led to the excavation of traces of occupation on the mainland around former coastlines. They all need to be documented and protected.

Archaeological evidence suggests an early penetration of the sea between the Geest island of Amrum and the Hallig island of Hooge. The Süderau tidal channel still indicates the direction of the incoming water at that time. Not only did it guide settlers in the first millennium but also caused a sea water intrusion as far as the Geestrand. On its way the water flooded an extensive area of peatland, brought its growth to an end and led to salt accumulation in the peat.

Large areas of peat, and the salt deposits found in it, were extracted systematically since the High Middle Ages. There is archaeological evidence of the extraction of salt peat in a narrow strip reaching west-east, from the Hallig islands of Hooge, Langeneß, Oland, Gröde and Habel to the mainland marshes and north to the southern periphery of the Wiedingharde.

Many traces of salt peat extraction have already been eroded by the North Sea, others have been covered by mainland marshes, Hallig islands and mudflats. Extensive erosion south of the Hallig island of Langeneß has led to the temporary exposure of peat extraction sites enclosed by former inland dykes

Salt was a much sought after commodity as the town charters of Ribe, Flensburg and Schleswig document and the extraction and trade of salt brought some temporary prosperity to the coast dwellers involved. This is mirrored in the distribution of sandstone sarcophagi imported from the Rhineland and Weser area and the correspondence between the distribution patterns of sarcophagi and extraction areas of salt peat were surely not accidental. The great flood of 1362 (Mandränke) caused the collapse of this flourishing salt-extraction industry. After 1362 the extraction of salt from previously untouched areas shows the lack of interest in the restoration of protective dykes destroyed by the Mandränke. The boom years of salt trade in North Frisia, however, were over.

The storm floods of the late Middle Ages not only turned peat extraction areas into mudflats again, but also permanently destroyed extensive areas of cultivated marsh. The area around the present Hallig island of Südfall, which is considered to be the site of the legendary

settlement of Rungholt in particular, was once again reclaimed by the sea. Finds and features of the 13th and 14th century allow, to some extent, the tracing back of the archaeology of the coastal landscape, which probably benefited primarily from the access to the open North Sea. At the same time this easy access to the open sea accelerated the decline of the settlements as an aggressive tidal channel, the present Norderhever, advanced, destroying all the protective dykes on its way north. On the whole the reasons for land loss during the Middle Ages were extremely diverse: not only the spatially varying subsidence of glacial sediments, sea level rise and increasing violence and frequency of storm-tides must be taken into account, but also other negative influences such as the Black Death, which appeared for the first time in the region of North Frisia in 1350 and must have decimated and weakened the population considerably.



Grådyb, Knudedyb, Juvre Dyb and the Lister Tief were important shipping routes between the mainland and the open sea since the Viking Age, and possibly even since the end of the Ice Age. Since the Middle Ages the growing number of larger ships meant that some areas of the Danish Wadden Sea gained importance as secure anchorages during storms and as places where cargo could be transhipped to smaller vessels or carts, such as Hviding Nakke or the east coast of Mandø. Commodities such as volcanic tuff, which was used as building material for medieval churches, are often found along the Danish Wadden Sea coast and we know about the export of large numbers of horses and cattle through the natural harbours and the tidal channels of the Wadden Sea to England from written sources. The cultural development of the Danish marsh and coastal region was also shaped by the Wadden Sea.

Early Modern Times

The Wadden Sea area in early modern times is characterised by three great themes; reclamation, international maritime conflict and international trade.

In the southern part of the Wadden Sea can be seen the remnants of the old dam to Ameland (the relict of a failed attempt in 1871-1882 to connect this island to the mainland as a first step in reclaiming this part of the Wadden Sea). This is still visible during the ebb tide and is worth protecting from a cultural-historical point of view. Other dams like the Geise

Leitdamm (opposite Emden), the Pollendam (near Harlingen), the Nieuwe Dam (West-Terschelling), and the dams alongside the river Weser by Ludwig Franzius, were built and function as training walls to influence the current. Minsener Oog was the result of an early 20th century attempt to deepen the Jade channel.

On the mud-flats bordering the salt-marshes, ditches and warping dams are witnesses of recent land reclamation. The most famous dam is the Afsluitdijk. This barrier dam, which is almost 30 km in length was completed in 1927-1932 and joins the coasts of the former island of Wieringen and Friesland. The Zuyder Zee was enclosed and shut off from its northern part with this great enclosure dike, forming the western part of the Dutch Wadden Sea.

In the northern half of the Wadden Sea the coastal dwellers of Dithmarschen proved to be as successful in the reclamation of new polders during early modern times as they had been in the Middle Ages. In North Frisia, however, it proved impossible to reclaim all the coastal land that had been cultivated during the Middle Ages. Archaeological finds show that during the 16th and early 17th century those areas which succeeded in empoldering at least parts of the coastal marshes gained in prosperity. The increase in affluence was, however, short-lived and as early as the 1st half of the 17th century storm-floods wreaked havoc again and caused significant losses of land. In particular the central part of the densely populated island of Strand was permanently lost and nothing but the islands of Pellworm and Nordstrand as well as the Hallig island of Nordstrandischmoor remained (see also the cultural entity descriptions of the Islands and Hallig islands). The extent of land loss can not only be traced through archaeological remains of settlements, dykes and cultivated land which are still found in the Wadden Sea, but also through the comparison of comparatively detailed maps of the late 16th and especially of the 1st half of the 17th century (J. Mejer, P. Sax, Q. C. Indervelden, J. Behrends, J. Wittemak) with modern topography.

The mobile evidence for human activities, such as maritime conflict and trade, in the form of ship-wrecks, have been found near the entrances to the Wadden Sea. Medieval and Early Modern water routes and harbour sites deserve special attention. The greatest number of historical wrecks have been recorded alongside the sailing routes in the west, to historical ports around the former Zuyder Zee like Amsterdam, Kampen, Enkhuizen, Hoorn, Stavoren and Harlingen. Some areas are especially promising e.g. the Texel Roads and the Vlie Roads (Vlieree). Because of the number of shipwrecks that have been traced (of Dutch East-Indiamen, medieval cogs and other merchantmen) the western part of the Dutch Wadden Sea was put on the Tentative List of World Heritage Sites. Apart from light-houses, buoyage and other maritime marks which derive their existence from daily sailing practices are mostly short-lived. The same applies to fishing-gear and fishing-grounds which are usually movable (e.g. hooks, bow-nets) and more or less constantly shifting (e.g. mussel-beds, eelgrass). Old fishermen's houses, harbours, museums, monuments and fishing-boats however can be found everywhere along the mainland and island coasts of the Wadden Sea. The same applies to maritime activities like pilotage and salvage. The buoyage-shed (tonnenloods) at the harbour in West-Terschelling, which is a centre of pilotage and used to be a salvage station (e.g. museum tugboat Holland) is a good example of the strong ties between the inhabitants of the area and the sea.

On the 16th of May 1644, during naval combat between Danish and Swedish warships near the northern tip of the island of Sylt, Danish man-of-wars blocked the way out through the Lister Tief between the islands of Sylt and Rømø. Due to a storm Swedish and Dutch ship were able to break through the blockade and escaped towards the open sea. Wrecks and anchors still mark the site of the battle in the Lister Tief between Denmark and Germany.



Modern Times

Human activity as well as natural forces have shaped the Wadden Sea Area. The causeways, most of which were built during the 1st half of the 20th century to the Hallig islands of Oland, Langeneß, Hamburger Hallig and Nordstrandischmoor and to the islands of Sylt and Nordstrand, have thus increased sedimentation in the near environment, but also cut off or diverted tidal streams. During the 20th century a causeway was built from the mainland to the Danish island of Rømø and a so-called Ebbevej to the island of Mandø. Modern reclamation of polders and regulations of the coastline (Meldorfer Bucht, Eidersperrwerk, Beltringharder Koog, Hauke-Haien Koog, Rickelsbüller Koog) have, however, had a much greater impact on the dynamics of the Wadden Sea. As a consequence the area available for flooding during high tides has been reduced considerably, affecting the water level and the tidal range, the long-term effects of these changes are still unclear. Unlike in North Frisia, temporary marshes have formed on the downwind sides of some offshore sandbanks in the Wadden Sea of Dithmarschen. Trischen, for example, had temporarily become almost an island in its own right. The marsh that had formed in the shelter of sand dunes was protected by dykes in 1922 thus creating the Marienpolder. The polder had, however, to be abandoned as early as 1943 when the movement of the sand dunes to the east could not be stopped and the sea defences became unsustainable.

Modern development and planning

The Wadden Sea is acknowledged by Denmark, Germany and The Netherlands as an area of major importance for biodiversity conservation, but also as a region in which people live, work and participate in recreation too. Different targets like environmental protection, safety, the need for sustainable development and economic development often impede each other and are thereby hampering decision-making.

Not only are the Geest islands and Hallig islands part of the Wadden Sea area, they are also sustained and protected by it. In the light of rising sea levels the Wadden Sea has grown in importance as a factor in coastal protection and land reclamation issues. Changes in the offshore zone caused by rising sea levels are important indicators of threats to the Wadden

substratum and the land remains which lie on top of it as well as all the structures that provide coastal protection. It is in the interest of the people who live on Hallig islands and close to sea defences to address the problems of rising sea levels, changes of the tidal range and an increasing violence and frequency of storm-tides.

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