



MarLIN

Marine Information Network

Information on the species and habitats around the coasts and sea of the British Isles

Dwarf eelgrass (*Zostera (Zosterella) noltei*)

MarLIN – Marine Life Information Network
Biology and Sensitivity Key Information Review

Dr Harvey Tyler-Walters

2005-10-14

A report from:

The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [<https://www.marlin.ac.uk/species/detail/1409>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

This review can be cited as:

Tyler-Walters, H., 2005. *Zostera (Zosterella) noltei* Dwarf eelgrass. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

DOI <https://dx.doi.org/10.17031/marlin.sp.1409.1>



The information (TEXT ONLY) provided by the Marine Life Information Network (MarLIN) is licensed under a Creative Commons Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License. Note that images and other media featured on this page are each governed by their own terms and conditions and they may or may not be available for reuse. Permissions beyond the scope of this license are available [here](#). Based on a work at www.marlin.ac.uk

(page left blank)



A bed of *Zostera noltei* with *Hydrobia ulvae* visible on the mud surface.

Photographer: Mark Davies

Copyright: Joint Nature Conservation Committee (JNCC)

See online review for
distribution map

Distribution data supplied by the Ocean Biogeographic Information System (OBIS). To interrogate UK data visit the NBN Atlas.

Researched by	Dr Harvey Tyler-Walters	Refereed by	Dr Leigh Jones
Authority	Hornemann		
Other common names	-	Synonyms	<i>Zostera nana</i> Roth, <i>Zostera noltii</i>

Summary

🔍 Description

Grass-like flowering plant with grass green, long, narrow, ribbon shaped leaves 6-22 cm in length and 0.5-1.5 mm wide with 3 irregularly spaced veins. The tips of the leaves are blunt, notched, often asymmetric, and become indented in older leaves. Leaves shoot from a creeping rhizome, 0.5-2 cm thick, with 1-4 roots per node, which binds the sediment. Leaves shoot in groups of 2-5, encased in a short, open, sheath 0.54 cm long. Several flowers (4-5 male and 4-5 female) occur on a spear-shaped reproductive shoot 2-25 cm long (usually 10cm). Seeds are smooth, white, and 1.5-2 mm in length (excluding the style). Leaves and rhizomes contain air spaces, lacunae, that aid buoyancy and keep the leaves upright when immersed.

📍 Recorded distribution in Britain and Ireland

Found in estuaries and bays around Britain with extensive populations in the Moray and Cromarty Firths, the Wash, Essex and Thames estuaries, Argyll and Clyde areas. It is also reported from Strangford Lough, Dungarvan Harbour and Dublin Bay in Ireland.

📍 Global distribution

Found along the Atlantic coasts of Europe, around the British Isles, from southern Norway to

Mauritania. Restricted to brackish conditions e.g. lagoons, river mouths in the Mediterranean and Black Sea. It is the only seagrass in the Caspian and Aral Sea.

Habitat

Grows in scattered clumps, dense beds or meadows on intertidal mud or detritus rich fine sand in the intertidal. It is particularly abundant between mean high water neaps and mean low water neaps, often forming a dense belt. Its upper and lower limits shift down shore with decreasing salinity, and in brackish waters (e.g. lagoons, étangs), it may become permanently submerged.

↓ Depth range

Intertidal

Q Identifying features

- Leaves grass green in colour.
- Leaf tips blunt and emarginate (notched), becoming indented in older leaves.
- Leaves 6 -22 cm long, 0.5-1.5 cm wide with 3 irregularly spaced veins.
- Leaf sheath short, 0.54 cm, and open with two membranous flaps.
- Reproductive shoots lateral.
- Seeds, 1.5-2 mm long (excluding style), white, and smooth.
- Rhizome 0.5-2 mm thick with 1-4 roots per node.
- Rhizome with fibre bundles in the innermost layers of the outer cortex.

Additional information

Like most of *Zostera* sp. this species may exhibit morphological variation depending on location, tidal zone and age of plant (Phillips & Menez, 1988).

✓ Listed by



Further information sources

Search on:



Biology review

☰ Taxonomy

Phylum	Tracheophyta Vascular plants (seagrasses, pondweeds, and reeds)	
Class	Magnoliopsida	
Order	Alismatales	
Family	Zosteraceae	
Genus	Zostera	Eelgrasses
Authority	Hornemann	
Recent Synonyms	Zostera nana RothZostera noltii	

🌿 Biology

Typical abundance	High density
Male size range	
Male size at maturity	
Female size range	Medium-large(21-50cm)
Female size at maturity	
Growth form	Foliose
Growth rate	See additional text
Body flexibility	High (greater than 45 degrees)
Mobility	Sessile
Characteristic feeding method	Autotroph
Diet/food source	
Typically feeds on	Not relevant
Sociability	Not relevant
Environmental position	Epifaunal, Infaunal
Dependency	Independent.
Supports	Host Numerous epiphytes, some specific to seagrasses and the parasitic fungus <i>Plasmodiophora bicaudata</i> Feldm.
Is the species harmful?	No No text entered

🏛️ Biology information

Growth

Growth in seagrasses is generally limited by light and affected by temperature (Philliparts, 1995a & b; Marta *et al.*, 1996). *Zostera noltei* is more tolerant of high light intensities, available at low tide, than *Zostera marina*, presumably an adaptation to life higher on the shore and the more turbid environment of intertidal flats (Vermaat *et al.*, 1996; Davison & Hughes, 1998). New leaves appear in spring and eelgrass meadows develop over intertidal flats in summer, due to vegetative growth. Increase in shoot density resulting from continuous branching of the rhizome (Vermaat & Verhagen, 1996). A shoot density of 1000-23000 /m was reported in the Zandkreek estuary, Netherlands (Vermaat & Verhagen, 1996). Leaf growth stops in September/October and leaves

are shed although *Zostera noltei* keeps its leaves longer than *Zostera marina* in winter. In the intertidal the combined action of grazing and wave action causes leaves to be lost over winter, and the plant reduced to its rhizomes within the sediment. For example, Nacken & Reise (2000) reported that 50% of leaves fell off while the rest were taken by birds (see importance) in the Wadden Sea. In the following season, regrowth occurs from the remaining rhizomes.

The rhizome of *Zostera noltei* is thinner than that of the longer lived *Zostera marina* and its growth is rapid and ephemeral in nature, taking advantage of seasonal increases in light and nutrients rather than metabolites stored in the rhizome (Marta *et al.*, 1996; Dawes & Guiry, 1992). Marta *et al.* (1996) reported shoot growth rates of ca 0.2 cm/day (winter minimum) to ca 0.8-0.9 cm/day (summer maximum) in the Mediterranean (with winter temperature of 12 °C and summer maximum temperature of 23.2 °C). They also stated that the rhizomes were short lived, <1 year, presumably from one growing season to the next, however given the 'life-span' of vegetative clones of *Zostera marina*, the plants and seagrass bed of *Zostera noltei* may be much older.

Epiphytes

The following algal species have been recorded only from seagrass leaves: *Halothrix lumbricalis*; *Leblondiella densa*; *Myrionema magnusii*; *Cladosiphon zosterae*; *Punctaria crispata* and *Cladosiphon contortus*, which is larger and found primarily on *Zostera* sp. rhizomes. Other species of algae are host specific for *Zostera marina*. The parasitic fungus *Plasmodiophora bicaudata* Feldm. prevented growth from rhizome internodes and gives the diseased plant a tufted appearance (den Hartog, 1970).

Productivity

Plus *et al.* (2001) reported the gross production rates of *Zostera noltei* beds in the Thau lagoon, France, to be between 97.5 - 1001.3 mg oxygen /m /h which was within the range reported for other temperate seagrass beds.

Habitat preferences

Physiographic preferences	Strait / sound, Sea loch / Sea lough, Ria / Voe, Estuary, Isolated saline water (Lagoon), Enclosed coast / Embayment
Biological zone preferences	Lower eulittoral, Mid eulittoral, Sublittoral fringe, Upper eulittoral
Substratum / habitat preferences	Mud, Muddy sand, Sandy mud
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Sheltered, Very sheltered
Salinity preferences	Full (30-40 psu), Low (<18 psu), Reduced (18-30 psu), Variable (18-40 psu)
Depth range	Intertidal
Other preferences	No text entered
Migration Pattern	Non-migratory / resident

Habitat Information

In non-tidal brackish waters the leaves may be wider than intertidal specimens. In Britain, mixed beds of *Zostera noltei* and *Zostera angustifolia* (see *Zostera marina* review) often occur on the shore.

However, the two species occupy different niches, *Zostera noltei* occurs on hummocks of free draining sediment while *Zostera angustifolia* is found in hollows that retain standing water at low tide.

The distribution of *Zostera noltei* in the intertidal may be affected by infaunal deposit feeders. For example, Philliparts (1994a) noted an abrupt cut off between a *Zostera noltei* bed and an area dominated by *Arenicola marina*. *Zostera noltei* was excluded from sediment dominated by *Arenicola marina*, while the lug worm itself was excluded from the *Zostera noltei* bed by the presence of a clay layer (Phillipart, 1994a). Similar separation has been noted between areas dominated by *Zostera noltei* or *Hediste diversicolor* (Hughes *et al.*, 2000).

Life history

Adult characteristics

Reproductive type	Vegetative
Reproductive frequency	Annual protracted
Fecundity (number of eggs)	No information
Generation time	1-2 years
Age at maturity	1-2 years
Season	May - September
Life span	See additional information

Larval characteristics

Larval/propagule type	-
Larval/juvenile development	Oviparous
Duration of larval stage	Not relevant
Larval dispersal potential	100 -1000 m
Larval settlement period	Not relevant

Life history information

Zostera sp. are monoecious perennials but may be annuals under stressful conditions (Phillips & Menez 1988). Hootsmans *et al.* (1987) reported that each flowering shoot of *Zostera noltei* produces 3-4 flowers containing 2-3 seed each. They estimated a potential seed production of 9000/m² based on the maximum density of flowering shoots in their quadrats in the Zandkreek, Netherlands. Most seeds were released in August in the Zandkreek but the actual seed densities were much lower than predicted (Hootsmans *et al.*, 1987). However, the density of flowering shoots is highly variable. Eelgrass reproduces vegetatively, i.e. by growth of rhizome. Vegetative reproduction probably exceeds seedling recruitment except in areas of sediment disturbance (Reusch *et al.* 1998; Phillips & Menez 1988). Phillips & Menez (1988) state that seedling mortality is extremely high. Fishman & Orth (1996) report that 96% of *Zostera marina* seeds were lost from uncaged test areas due to transport (dispersal) or predation. Hootsmans *et al.* (1987) noted that potential recruitment was maximal (32% of seeds) at 30 °C and 10psu, and no recruitment occurred at 30psu. and they estimated that, in 1983 <5% of *Zostera noltei* plants in the Zandkreek originated from seed. Phillips & Menez (1988) note that seedlings rarely occur within the eelgrass

beds except in areas cleared by storms, blow-out or excessive herbivory. Den Hartog (1970) noted that although the seed set was high, *Zostera noltei* seedlings were rarely seen in the wild, suggesting that vegetative reproduction may be more important than sexual reproduction (Davison & Hughes, 1998). Experimental germination was increased by low salinity (1-10 psu) in *Zostera noltei* and no germination occurred at salinities above 20 psu, however germination was independent of temperature (Hughes *et al.*, 2000).

Sexual reproduction

Zostera sp. flowers release pollen in long strands, dense enough to remain at the depth they were released for several days, therefore, increasing their chance of pollinating receptive stigmas. Seeds develop within a membranous wall that photosynthesises, developing an oxygen bubble within the capsule, eventually rupturing the capsule to release the seed. Seeds generally sink and may be dispersed by currents and waves (perhaps aided by air bubbles) and the feet or gut of birds.

Methods of dispersal:

- All parts of the plant may float if they become detached from substratum. Pieces of rhizome or shoots (if displaced by for example storm action) may take root if they settle on suitable substrata (Phillips & Menez, 1988).
- The generative stalk may be released together with the seed complement and may be carried great distances (Phillips & Menez, 1988).
- In New York, USA, Churchill *et al.* (1985) recorded 5-13% of *Zostera marina* seeds with attached gas bubbles and achieved an average dispersal distance of 21m and up to 200m in a few cases.
- Wildfowl may disperse seeds on their feet, or in their gut. For example, 30% of freshwater eelgrass (*Naja marina*) seeds fed to ducks in Japan survived and successfully germinated after passage through their alimentary canals and potentially transported 100-200km (Fishman & Orth 1996).

Sensitivity review

This MarLIN sensitivity assessment has been superseded by the MarESA approach to sensitivity assessment. MarLIN assessments used an approach that has now been modified to reflect the most recent conservation imperatives and terminology and are due to be updated by 2016/17.

A Physical Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Substratum Loss	High	Low	High	Moderate

The rhizome occupies the top 20cm of the substratum. Substratum loss will result in the loss of the shoots, rhizome and probably the seed bank. Recoverability will depend on recruitment from other populations. Although *Zostera* sp. seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt *et al.* (1997) suggested that recovery would take between 5-10 years, but in many cases longer. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continued decline of *Zostera noltei* beds suggests that, once lost, eelgrass beds take considerable time to re-establish.

Smothering	High	Low	High	Moderate
-------------------	------	-----	------	----------

Sediment disturbance, siltation, erosion and turbidity resulting from coastal engineering and dredging activities have been implicated in the decline of seagrass beds world wide (Davison & Hughes, 1998; Holt *et al.*, 1997). Seagrasses are intolerant of smothering and typically bend over with addition of sediment and are buried in a few centimetres of sediment (Fonseca, 1992). *Zostera* sp. are highly intolerant of smothering by epiphytes or algal mats (see nutrients). Recoverability will depend on recruitment from other populations. Although *Zostera* sp. seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt *et al.* (1997) suggested that recovery would take between 5-10 years, but in many cases longer. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continued decline of *Zostera noltei* beds suggests that, once lost, eelgrass beds take considerable time to re-establish.

Increase in suspended sediment	Intermediate	High	Low	Moderate
---------------------------------------	--------------	------	-----	----------

Increased sediment availability may result in raised eelgrass beds or smothering of the leaves. Decreased sedimentation is likely to result in erosion and loss of the eelgrass beds. Sediment deposited during summer months may be lost again due to winter storms, resuspension by grazing wildfowl, and increased erosion due to die back of leaves and shoots in autumn and winter.

The grazing and digging activity of brent geese and wigeon may increase erosion of intertidal beds during winter months, but in doing so compensate for the sediment deposited during summer months, which may be beneficial to growth of *Zostera noltei* beds (Nacken & Reise, 2000). The rhizome is probably able to grow through deposited sediment, e.g. Mediterranean *Zostera noltei* is able to grow upward, through 2 cm of substratum in 4 months (Vermaat *et al.*,

1996). Therefore, *Zostera noltei* beds are probably tolerant of annual or temporary changes in siltation and sedimentation rates.

However, increased sediment erosion or accretion have been associated with loss of seagrass beds in the Australia, the Mediterranean, the Wadden Sea, and USA. Sediment dynamics and hydrodynamics are key factors in seagrass systems (Asmus & Asmus, 2000a; Davison & Hughes, 1998; Holt *et al.*, 1997). Overall, therefore, seagrass beds are probably intolerant of any activity that changes the sediment regime where the change is greater than expected due to natural events in magnitude or duration and an intolerance of intermediate has been reported. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continuing decline of *Zostera noltii* beds suggests that, once lost, eelgrass beds take considerable time to re-establish. However, evidence from grazing studies suggest that *Zostera noltii* beds can recover within a year after removal of 63% of plant biomass (Nacken & Reise, 2000). Similarly, Dawes & Guiry (1992) regarded *Zostera noltei* as ephemeral in nature. However, where a bed is stressed by other factors, recovery may be delayed (Holt *et al.* 1997; Davison & Hughes 1998).

Increased suspended sediment concentrations will also decrease light penetration (see turbidity).

Decrease in suspended sediment

Dessication

Low

Very high

Very Low

Zostera noltei is more tolerant of desiccation than other *Zostera* species, indicated by its intertidal position and ability to colonize well draining sediment. In well -drained areas *Zostera noltei* may dry out completely between tides (Davison & Hughes, 1998). However, little information on desiccation tolerance was found.

Increase in emergence regime

Intermediate

High

Low

Low

Zostera noltei is abundant between mean high water neaps and mean low water neaps. It can survive higher on the shore than *Zostera angustifolia* although they are often sympatric. Intertidal seagrasses are adapted to leaf and sediment loss due to wave action, grazing and the re-suspension of sediment resulting in high turbidities (Vermaat *et al.*, 1996). Although the intertidal is likely to be affected by high turbidity, *Zostera noltei* probably makes up for this lack of light by utilising the high levels of light availability when emmersed. It can tolerate higher light intensities than other seagrasses (Vermaat *et al.*, 1996; Davison & Hughes, 1998). Philippart (1995b) noted that although tolerant of high light intensities, its upper shore extent was limited by desiccation tolerance, and the optimal intertidal position of *Zostera noltei* on a tidal flat near Terschelling, Wadden Sea, was 50% emersion.

A long term change in the emergence regime is likely to increase or reduce the extent of the population in the intertidal. An increase in emergence is likely to reduce its upper extent although this may be compensated for increased growth lower on the shore. Decreased emergence is likely to enable to seagrass bed to expand further up the shore. However, expansion depends on available habitat and competition in infaunal dominated sediments (e.g. *Hediste diversicolor* or *Arenicola marina* (Hughes *et al.*, 2000; Philippart, 1994a).

The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease

and the continuing decline of *Zostera noltei* beds suggests that, once lost, eelgrass beds take considerable time to re-establish. However, evidence from grazing studies suggest that *Zostera noltii* beds can recover within a year after removal of 63% of plant biomass (Nacken & Reise, 2000). Similarly, Dawes & Guiry (1992) regarded *Zostera noltei* as ephemeral in nature. However, where a bed is stressed by other factors, recovery may be delayed (Holt *et al.* 1997; Davison & Hughes 1998).

Decrease in emergence regime

Increase in water flow rate

Intermediate

High

Low

Low

Zostera noltei beds typically occur where water flow rates are weak or negligible. Increased flow rates are likely to erode sediment, expose rhizomes and lead to loss of the plants. Increased water flow rates deposit coarser sediments and erode fine sediments resulting in loss of suitable substrata for this species.

The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continuing decline of *Zostera noltii* beds suggests that, once lost, eelgrass beds take considerable time to re-establish. However, evidence from grazing studies suggest that *Zostera noltei* beds can recover within a year after removal of 63% of plant biomass (Nacken & Reise, 2000). Similarly, Dawes & Guiry (1992) regarded *Zostera noltei* as ephemeral in nature. However, where a bed is stressed by other factors, recovery may be delayed (Holt *et al.* 1997; Davison & Hughes 1998).

Decrease in water flow rate

Increase in temperature

Tolerant

Not relevant

Not sensitive

Not relevant

Populations of *Zostera noltei* occur from the Mediterranean to southern Norway and *Zostera* sp. are regarded as tolerant of temperatures between about 5 - 30°C. Therefore, they may tolerate the range of temperatures likely in the British Isles (Davison & Hughes, 1998). Intertidal populations may be damaged by frost (Hartog, 1987) and Covey & Hocking (1987) reported defoliation of *Zostera noltii* in the upper reaches of mudflats in Helford River due to ice formation in the exceptionally cold winter of 1987. However, the rhizomes survived and leaves are usually lost at this time of year due to shedding, storms or grazing with little apparent effect (Nacken & Reise, 2000). Populations at the edge of the range are likely to be more intolerant of temperature change. Phillips & Menez (1988) reported death of seagrass as the result of a thermal plume in Biscayn Bay, Florida that raised ambient temperature by 5°C, however, the species concerned were not cited. Long term temperature increase may increase the relative contribution of sexual reproduction and seed germination to population structure.

Decrease in temperature

Increase in turbidity

Intermediate

High

Low

Low

Increased turbidity due to suspended sediment, humic substances, riverine discharges or phytoplankton growth reduces the light reaching submerged plants. Increase turbidity has been associated with the continued decline of seagrass beds world-wide (Philippart, 1994; Davison & Hughes, 1998; Asmus & Asmus, 2000). However, intertidal *Zostera noltei* 'escapes'

this turbidity since it is able to take advantage of the high light intensities available at low tide (Vermaat *et al.*, 1996). Furthermore, *Zostera noltei* can store and mobilize carbohydrates and has been reported to be able to tolerate acute light reductions (below 2% of surface irradiance for two weeks) (Peralta *et al.*, 2002). However, *Zostera noltei* are likely to be more intolerant to chronic increases in turbidity. Philippart (1994b) suggested that the declines in *Zostera noltei* beds in the Wadden Sea probably occurred at low water level. Permanently submerged population in brackish conditions may be more intolerant of increased turbidity. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continuing decline of *Zostera noltei* beds suggests that, once lost, eelgrass beds take considerable time to re-establish. However, evidence from grazing studies suggest that *Zostera noltei* beds can recover within a year after removal of 63% of plant biomass (Nacken & Reise, 2000). Similarly, Dawes & Guiry (1992) regarded *Zostera noltii* as ephemeral in nature. However, where a bed is stressed by other factors, recovery may be delayed (Holt *et al.* 1997; Davison & Hughes, 1998).

Decrease in turbidity

Increase in wave exposure

High

Low

High

Moderate

Seagrasses require sheltered environments, with gentle longshore currents and tidal flux. Increased wave exposure may increase sediment erosion (see siltation above). Populations present in moderately strong currents may benefit from decreased water flow rates. Small patchy populations or recently established population and seedling may be highly intolerant of increased wave action since they lack an extensive rhizome system.

Recoverability will depend on recruitment from other populations. Although *Zostera* sp. seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt *et al.* (1997) suggested that recovery would take between 5-10 years, but in many cases longer. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease and the continued decline of *Zostera noltei* beds suggests that, once lost, eelgrass beds take considerable time to re-establish.

Decrease in wave exposure

Noise

Tolerant

Not relevant

Not sensitive

The effect of sound waves and vibration on plants is poorly studied. It is likely that sound waves will have little effect at the benchmark levels suggested. Wildfowl are intolerant of disturbance by noise, which may reduce grazing pressure on intertidal *Zostera noltei*. However, Naken & Reise (2000) suggested that grazing was important for the persistence of *Zostera noltei* beds, at least in their study area.

Visual Presence

Tolerant

Not relevant

Not sensitive

High

Plants have no known visual receptors and are therefore, not sensitive to this factor. Wildfowl are intolerant of disturbance by visual presence of activities, which may reduce grazing pressure on intertidal *Zostera noltei*. However, Naken & Reise (2000) suggested that grazing was important for the persistence of *Zostera noltei* beds, at least in their study area.

Abrasion & physical disturbance

Intermediate

High

Low

Moderate

Seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activities that disturb the sediment (Holt *et al.*, 1997; Davison & Hughes, 1998). Small scale sediment disturbance may actually stimulate growth and small patches of sediment allow recolonization by seedlings. Rhizomes are likely to be damaged, leaf blades removed and seeds buried too deep to germinate, by activities such as trampling, anchoring, digging, dredging, power boat and jet-ski wash. For example, damage after the *Sea Empress* oil spill was reported as limited to the ruts left by clean up vehicles (Jones *et al.*, 2000). Brent geese feed on shoots, rhizomes, and roots, reworking the top centimetre of sediment (8 times in 3 months), and in the process dig pits 3-10cm deep by trampling. As a result, in the Wadden Sea from Sept-Dec (the over-wintering period) Brent geese removed 63% of the plant biomass and pitted 12% of the seagrass bed. However, the bed of *Zostera noltei* recovered by the following year, and the authors suggested that grazing and bioturbation was necessary for the persistence of the intertidal seagrass beds (Nacken & Reise, 2000). Similarly, several authors have suggested that *Zostera* sp. can recover from 'normal' levels of wildfowl grazing (Davison & Hughes, 1998). However, suction dredging for cockles in Solway Firth removed *Zostera* in affected areas while *Zostera* was abundant in un-dredged areas (Perkins, 1988). Therefore, the passage of a scallop dredge through the seagrass bed (see benchmark) will probably remove a proportion of the seagrass population and intolerance has been assessed as intermediate. Recoverability is likely to be high (see additional information below). However, seagrass beds are likely to be of higher intolerance to repeated scallop dredging or suction dredging.

Displacement

Intermediate

High

Low

Low

Seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activities that disturb the sediment (Holt *et al.*, 1997; Davison & Hughes, 1998). The seagrass bed is unlikely to survive displacement. Evidence from grazing studies suggest that *Zostera noltei* beds can recover within a year after removal of 63% of plant biomass (Nacken & Reise, 2000). Similarly, Dawes & Guiry (1992) regarded *Zostera noltei* as ephemeral in nature. However, where a bed is stressed by other factors, recovery may be delayed (Holt *et al.* 1997; Davison & Hughes 1998).

Increased suspended sediment concentrations will also decrease light penetration (see turbidity). However, Phillips & Menez (1988) reported that rhizomes and shoots can root and re-establish themselves if they settle on sediment long enough.

 Chemical Pressures

Intolerance

Recoverability

Sensitivity

Confidence

Synthetic compound contamination

Intermediate

High

Low

Moderate

There was little information on the effects of chemical contaminants on *Zostera noltei* and what little was found mainly refers to *Zostera marina*. *Zostera marina* is known to accumulate TBT but no damage was observable in the field (Williams *et al.*, 1994). Naphthalene, pentachlorophenol, Aldicarb and Kepone reduce nitrogen fixation and may affect *Zostera marina* viability. Triazine herbicides (e.g. Irgarol) inhibit photosynthesis and sublethal effects have been detected. Terrestrial herbicides may damage eelgrass beds in the marine environment. For example, the herbicide Atrazine is reported to cause growth inhibition and

50% mortality in *Zostera marina* exposed to 100 ppb (ng/l) Atrazine for 21 days (Davison & Hughes 1998). Bester (2000) noted a correlation between raised concentrations of 4 triazine herbicides and areas where *Zostera* sp. had been lost.

Heavy metal contamination

Low

Very high

Very Low

Low

Little information was found regarding heavy metal concentrations in *Zostera noltei* however, the following information was found for *Zostera marina*. The concentration and toxicity of heavy metals in salt marsh plants, including *Zostera marina* was reviewed by Williams *et al.*, 1994. Growth of *Zostera marina* is inhibited by 0.32 mg/l Cu and 10 mg/l Hg, but Cd, Zn, Cr and Pb had measurable but less toxic effects (Williams *et al.*, (1994). Davison & Hughes (1998) report that Hg, Ni and Pb reduce nitrogen fixation which may affect viability. However, leaves and rhizomes accumulate heavy metals, especially in winter. Williams *et al.* (1994) did not observe any damage to *Zostera marina* in the field. Williams *et al.* (1994) noted that the major route for uptake of heavy metals was through the leaves and suggested that intertidal populations would accumulate less heavy metals due to their reduced exposure.

Hydrocarbon contamination

High

High

Moderate

Moderate

- Healthy populations of *Zostera* can occur in the presence of long term, low level, hydrocarbon effluent, for example in Milford Haven, Wales (Hiscock, 1987; Davison & Hughes, 1998)
- *Zostera noltei* is likely to be more vulnerable from direct contact by oil due to its intertidal habitat (Davison & Hughes, 1998; Jones *et al.*, 2000)
- The Amoco Cadiz oil spill off Roscoff blackened *Zostera marina* leaves for 1-2 weeks but had little effect on growth, production or reproduction after the leaves were covered in oil for six hours (Jacobs, 1980).
- Experimental treatment of *Zostera noltei* with crude oil and dispersants halted growth but had little effect on cover. However, pre-mixed oil and dispersant caused rapid death and significant decline in cover (from 55% to 15% within 1 week suggesting that dispersant treatments should be avoided (Holden & Baker, 1980; Howard *et al.*, 1989; Davison & Hughes, 1998).
- Oil contamination could result in smothering of the plants, especially in the low energy conditions in which the *Zostera noltei* is often found (L. Jones, pers. comm.).

The effects of hydrocarbon contamination on *Zostera noltii* will depend on the type of oil spilled (L. Jones, pers. comm.). Removal of oil intolerant grazers, e.g. gastropods or amphipods, may result in smothering of eelgrasses by epiphytes or algal mats (see nutrients below and LMS.Znol).

Radionuclide contamination

Not relevant

Not relevant

Insufficient information

Changes in nutrient levels

Intermediate

High

Low

Moderate

Increased nutrient concentrations (nitrates and phosphates) have been implicated in the continued decline of seagrass beds world-wide, either directly or due to eutrophication

(Phillips & Menez, 1988; Davison & Hughes, 1998; Philippart, 1994b; Philippart, 1995a, b; Vermaat *et al.*, 1994; Asmus & Asmus, 2000). The following effects on *Zostera* sp. have been attributed to nutrients and eutrophication.

- High nitrate concentrations implicated in decline of *Zostera marina*. Burkholder *et al.* (1992) demonstrated that nitrate enrichment could cause decline of *Zostera marina* in poorly flushed areas. In addition they noted that increasing or high temperatures associated with spring exacerbated the adverse effects of nitrate enrichment and that growth and survival were significantly reduced by nutrient enrichment levels of between 3.5 and 35 μ Molar nitrate/day with the most rapid decline (weeks) at high nitrate levels. Plant loss resulted from death of the meristem tissue.
- van Katwijk *et al.* (1999) noted that adverse effects of nitrate were dependent on salinity. Estuarine *Zostera marina* plants were more intolerant of high nitrate concentration than marine *Zostera marina* plants at high (30 psu) salinity than at lower salinities (23 psu) and that both populations benefited from nitrate enrichment (0-4 to 6.3 μ Molar nitrate per day) at 23 or 26 psu.
- Increased growth of epiphytes or blanketing algae, for example:
 - Den Hartog (1994) reported the growth of a dense blanket of *Ulva radiata* in Langstone Harbour in 1991 that resulted in the loss of 10ha of *Zostera marina* and *Zostera noltei*. Subsequently, by summer 1992, the *Zostera* sp. were absent, however this may have been exacerbated by grazing by Brent geese
 - Philippart (1995b) reported that shading by periphyton reduced incident light reaching the leaves of *Zostera noltei* by 10-90% and reduced the period of time that net photosynthesis could occur by 2-80% depending on location.
 - Philippart (1995b) estimated that the mud-snail *Hydrobia ulvae* could remove 25-100% of the periphyton and microphytobenthos, and suggested that the decline of *Zostera noltii* in the Wadden Sea in the 1970s was in part due to increased periphyton growth due to eutrophication, and a simultaneous decline of the mud-snail population (although mud-snail populations have increased subsequently) (Philippart, 1995a).
- Encouragement of phytoplankton blooms which increase turbidity and reduce light penetration, although this may be of less significance for intertidal *Zostera noltii* populations (see above) (Davison & Hughes, 1998).
- The levels of phenolic compounds in *Zostera* sp. (involved in disease resistance) are reduced under nutrient enrichment and may increase their susceptibility to infection by wasting disease (Buchsbaum *et al.*, 1990; Burkholder *et al.*, 1992).

Long-term increases in nutrients or eutrophication may result in loss of the intertidal eelgrass beds.

Increase in salinity

Low

Very high

Very Low

Low

Zostera sp. have a wide tolerance of salinity from 10 - 39 ppt (Davison & Hughes 1998), although den Hartog (1970) suggested a lower salinity tolerance of 5 psu for *Zostera* sp. Den Hartog (1970) stated that *Zostera noltii* was a euryhaline species, penetrating estuaries and the Baltic Sea to the average annual isohaline of 9-10 psu. *Zostera noltei* is probably more tolerant of extremes of salinity than its congeners due to its intertidal habit and *Zostera* sp. occupy a wide range of salinities, therefore 'low' intolerance has been recorded.

Decrease in salinity

Changes in oxygenation **Low** **Very high** **Very Low** **Low**

The effects of oxygen concentration on the growth and survivability of *Zostera noltei* are not reported in the literature. *Zostera* sp. leaves contain air spaces (lacunae) and oxygen is transported to the roots where it permeates into the sediment, resulting in a oxygenated microzone. This enhances the uptake of nitrogen. The presence of air spaces suggests that seagrass may be tolerant of low oxygen levels in the short term, however, prolonged deoxygenation, especially if combined with low light penetration and hence reduced photosynthesis may have an effect.

 **Biological Pressures**

Introduction of microbial pathogens/parasites **Intolerance** **Recoverability** **Sensitivity** **Confidence**
Intermediate **Very high** **Low** **High**

A major outbreak of wasting disease resulted in significant declines of *Zostera* beds on both sides of the Atlantic in 1920s to 1930s, primarily *Zostera marina* in the subtidal. Wasting disease is thought to be caused by the marine fungus, *Labyrinthula macrocystis*. The disease causes death of leaves and after 2-3 seasons death of regenerative shoots, rhizomes and loss of up to 90 percent of the population. The disease is less likely at low salinities however, and *Zostera noltei* was little affected (Rasmussen, 1977; Davison & Hughes, 1998). Decline of intertidal *Zostera marina* and *Zostera noltei* beds in the Wadden Sea began in the 1960s and a marked decline in *Zostera noltei* occurred between 1965 and 1975, presumably due to anthropogenic change (Philippart, 1994b).

Introduction of non-native species **Intermediate** **Low** **High** **Moderate**

Spartina anglica (a cord grass) is an invasive pioneer species, a hybrid of introduced and native cord grass species. Its rapid growth consolidates sediment, raises mudflats and reduces sediment availability elsewhere. It has been implicated in the reduction of common eelgrass cover in Lindisfarne, Northumberland due to encroachment and changes in sediment dynamics. Wire weed (*Sargassum muticum*) invades open substratum and may prevent recolonization of areas of eelgrass beds left open by disturbance (Davison & Hughes 1998). *Zostera marina* and *Sargassum muticum* may compete for space in the lower shore lagoons of the Solent. However, evidence for competition is conflicting and requires further research. If the invasive species prevents recolonization then recoverability from other factors will be reduced. Intertidal *Zostera noltei* may be more vulnerable to competition from *Spartina* sp.

Extraction of this species **Intermediate** **High** **Low** **Moderate**

Wildfowl grazing can consume significant amounts of seagrass and reduce cover mainly in autumn and winter. Tubbs & Tubbs (1983) reported that Brent geese reduced the cover of *Zostera marina* and *Zostera noltei* from 60-100% to 5-10% in mid October to mid January in the Solent. Grazing is probably part of the natural seasonal fluctuation in seagrass cover and *Zostera* sp. can recover from normal grazing (Naken & Reise, 2000; Davison & Hughes, 1998).

Zostera noltei is the preferred food of the dark-bellied Brent goose (*Branta bernicla*). Brent geese feed on shoots, rhizomes and roots, reworking the top centimetre of sediment (8 times in 3 months), and in the process dig pits 3-10cm deep by trampling. As a result, in the Wadden Sea from Sept-Dec (the over-wintering period) Brent geese removed 63% of the plant biomass and pitted 12% of the seagrass bed. However, the bed of *Zostera noltei* recovered by the following year, and the authors suggested that grazing and bioturbation was necessary for the persistence of the intertidal seagrass beds (Nacken & Reise, 2000). However, where a bed is stressed by other factors it may not be able to withstand grazing (Holt *et al.* 1997; Davison & Hughes 1998). For example, seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activities that disturb the sediment. A seagrass bed is unlikely to survive displacement or extraction, although Phillips & Menez (1988) reported that rhizomes and shoots can root and re-establish themselves if they settle on sediment long enough. Therefore, *Zostera noltei* beds have been considered to be of 'intermediate' intolerance to extraction.

Extraction of other species

High

Low

High

High

Zostera sp. are regarded as very intolerant of hydraulic bivalve fishing in the UK and Wadden Sea (Holt *et al.*, 1997; Davison & Hughes, 1998; Philippart, 1994b). Cockles and *Zostera noltei* are frequently associated and intertidal beds may be more vulnerable (Holt *et al.*, 1997). Hydraulic dredging is likely to break up and remove rhizomes. It was suggested that hydraulic harvesting of cockles in the Solway Firth could cause widespread damage or eradicate *Zostera* sp. from the bay (Perkins, 1988). Digging and dredging for the American hard-shell clam (*Merценaria mercenaria*) had a significant effect on the eelgrass beds (Cox, 1991; Eno *et al.*, 1997). In the Dutch Wadden Sea, seagrass is hardly found where cockles are normally fished (Dankers & de Vlas, 1992). Recovery was severely restricted especially where no rhizomes and roots were left in the sediment (De Jong & de Jong, 1992; Philippart, 1994b).

Additional information

No text entered.

Importance review

Policy/legislation

IUCN Red List Least Concern (LC)

Status

National (GB) importance	Nationally scarce	Global red list (IUCN) category	Least Concern (LC)
--------------------------	-------------------	---------------------------------	--------------------

Non-native

Native	-	Date Arrived	Not relevant
Origin	-		

Importance information

Zostera noltei is included in a Habitat Action Plan under the UK Biodiversity Action Plan. Seagrass beds are recognised internationally as important coastal ecosystems (Asmus & Asmus, 2000a & b).

- seagrass beds are highly productive ecosystems which are utilised directly by grazers such as wildfowl and export their productivity in the form of detritus to support surrounding benthic communities;
 - seagrass support a diverse epifauna, epiflora and infauna, although intertidal beds are have lower species diversity than subtidal beds;
 - seagrass beds are important sediment traps, stabilize the sediment, reduce the incident wave energy and may act as a natural coastal defence (Davison & Hughes, 1998);
 - loss of seagrass beds have resulted in profound changes in the material budget, food web and ecosystem (Asmus & Asmus, 2000a & b);
- Zostera* is an important component of the diet of Brent geese (*Branta bernicla*), wigeon (*Anas penelope*), mute and whooper swans (*Cygnus olor* and *Cygnus cygnus*);
- the Brent geese population in Europe declined as a result of the decline in eelgrass populations due to wasting disease (den Hartog, 1970; Phillips & Menez, 1988; Davison & Hughes, 1998; Asmus & Asmus, 2000b).

Zostera noltei has replaced *Zostera marina* as the preferred food species for Brent geese (Tubbs & Tubbs, 1982; Davison & Hughes, 1998).

Sea grasses have been put to a number of uses in the past for example, sound-proofing, insulation, roofing thatch, binding soil, packaging, basket weaving and in the manufacture of 'coir' matting (see Kuelan, 1999 for review).

Bibliography

- Anonymous, 1999p. Seagrass beds. Habitat Action Plan. In *UK Biodiversity Group. Tranche 2 Action Plans. English Nature for the UK Biodiversity Group, Peterborough., English Nature for the UK Biodiversity Group, Peterborough.*
- Asmus, H. & Asmus, R., 2000a. ECSA - Workshop on intertidal seagrass beds and algal mats: organisms and fluxes at the ecosystem level. (Editorial). *Helgoland Marine Research*, **54**, 53-54.
- Asmus, H. & Asmus, R., 2000b. Material exchange and food web of seagrasses beds in the Sylt-Rømø Bight: how significant are community changes at the ecosystem level? *Helgoland Marine Research*, **54**, 137-150.
- Bester, K., 2000. The effects of pesticides on seagrass beds. *Helgoland Marine Research*, **54**, 95-98.
- Brazier, D.P., Holt, R.H.F., Murray, E. & Nichols, D.M., 1999. *Marine Nature Conservation Review Sector 10. Cardigan Bay and North Wales: area summaries*. Peterborough: Joint Nature Conservation Committee. [Coasts and seas of the United Kingdom. MNCR Series.]
- Buchsbaum, R.N., Short, F.T. & Cheney, D.P., 1990. Phenolic-nitrogen interactions in eelgrass *Zostera marina*: possible implications for disease resistance. *Aquatic Botany*, **37**, 291-297.
- Burkholder, J.M., Mason, K.M. & Glasgow, H.B. Jr., 1992. Water-column nitrate enrichment promotes decline of eelgrass *Zostera marina*: evidence from seasonal mesocosm experiments. *Marine Ecology Progress Series*, **81**, 163-178.
- Churchill, A.C., Nieves, G. & Brenowitz, A.H., 1985. Floatation and dispersal of eelgrass seeds by gas bubbles. *Estuaries*, **8**, 352-354.
- Covey, R. & Hocking, S., 1987. Helford River Survey. *Report for the Heinz, Guardians of the Countryside and World Wide Fund for Nature*, 121 pp.
- Cox, J., 1991. Dredging for the American hard-shell clam - implications for nature conservation. *Ecosystems. A Review of Conservation*, **12**, 50-54.
- Dankers, N. & de Vlas, J., 1992. Multifunctioneel beheer in de Waddenzee, integratie van natuurbeheer en schelpdiervisserij. *Institute for Forestry and Nature Research, RIN Report*, no. 92/15, 18pp.
- Davison, D.M. & Hughes, D.J., 1998. *Zostera* biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs, Vol. 1. *Scottish Association for Marine Science, (UK Marine SACs Project), Scottish Association for Marine Science, (UK Marine SACs Project), Vol. 1., <http://www.english-nature.org.uk/uk-marine>*
- Dawes, C.J. & Guiry, M.D., 1992. Proximate constituents in the seagrasses *Zostera marina* and *Z. noltii* in Ireland. *Marine Ecology*, **13**, 307-315.
- de Jonge, V.N. & de Jonge, D.J., 1992. Role of tide, light and fisheries in the decline of *Zostera marina*. *Netherlands Institute of Sea Research Publications Series* no. 20, pp. 161-176.
- Den Hartog, C., 1970. *The sea-grasses of the world*. Amsterdam: North Holland Publishing Company.
- Den Hartog, C., 1994. Suffocation of a littoral *Zostera* bed by *Enteromorpha radiata*. *Aquatic Botany*, **47**, 21-28.
- Eno, N.C., Clark, R.A. & Sanderson, W.G. (ed.) 1997. *Non-native marine species in British waters: a review and directory*. Peterborough: Joint Nature Conservation Committee.
- Fishman, J.R. & Orth, R.J., 1996. Effects of predation on *Zostera marina* L. seed abundance. *Journal of Experimental Marine Biology and Ecology*, **198**, 11-26.
- Hiscock, S., 1987. A brief account of the algal flora of *Zostera marina* beds in the Isle of Scilly. In *Sublittoral monitoring in the Isles of Scilly 1985 & 1986* (ed. R. Irving). *Nature Conservancy Council, Peterborough.*
- Holden, P. & Baker, J.M., 1980. Dispersant-treated compared with untreated crude oil. *Experiments with oil and dispersants on the seagrass Zostera noltii*. *Report to the Advisory Committee on Pollution of the Sea, Field Studies Council.*
- Holt, T.J., Hartnoll, R.G. & Hawkins, S.J., 1997. The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, *Zostera* beds and *Sabellaria spinulosa* reefs. *English Nature, Peterborough, English Nature Research Report No. 234.*
- Hootsmans, M.J.M., Vermaat, J.E. & Vierssen, van W., 1987. Seed-bank development, germination and early seedling survival of two seagrass species from the Netherlands: *Zostera marina* L. and *Zostera noltii* Hornem. *Aquatic Botany*, **28** (3), 275-285
- Howard, S., Baker, J.M. & Hiscock, K., 1989. The effects of oil and dispersants on seagrasses in Milford Haven. In *Ecological Impacts of the Oil Industry*, (ed. B. Dicks), pp. 61-96. Chichester: John Wiley & Sons Ltd. for the Institute of Petroleum, London.
- Hughes, R.G., Lloyd, D., Ball, L., Emson, D., 2000. The effects of the polychaete *Nereis diversicolor* on the distribution and transplantation success of *Zostera noltii*. *Helgoland Marine Research*, **54**, 129-136.
- Jacobs, R.P.W.M., 1980. Effects of the *Amoco Cadiz* oil spill on the seagrass community at Roscoff with special reference to the benthic infauna. *Marine Ecology Progress Series*, **2**, 207-212.
- Jones, L.A., Hiscock, K. & Connor, D.W., 2000. Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. *Joint Nature Conservation Committee, Peterborough. (UK Marine SACs Project report.)*. Available from: <http://www.ukmarinesac.org.uk/pdfs/marine-habitats-review.pdf>
- Katwijk van, M.M., Schmitz, G.H.W., Gasseling, A.P., & Avesaath van, P.H., 1999. Effects of salinity and nutrient load and their interaction on *Zostera marina*. *Marine Ecology Progress Series*, **190**, 155-165.

- Kuelan, van M., 1999. Human uses of seagrass. http://possum.murdoch.edu.au/~seagrass/seagrass_uses.html, 2000-01-01
- Madden, B., Jennings, E. & Jeffrey, D.W., 1993. Distribution and ecology of *Zostera* in Co. Dublin. *The Irish Naturalists' Journal*, **24**, 303-310.
- Marta, N., Cebrian, J., Enriquez, S. & Duarte, C.M., 1996. Growth patterns of western Mediterranean seagrasses: species specific responses to seasonal forcing. *Marine Ecology Progress Series*, **133**, 203-215.
- Nacken, M. & Reise, K., 2000. Effects of herbivorous birds on intertidal seagrass beds in the northern Wadden Sea. *Helgoland Marine Research*, **54**, 87-94.
- Olesen, B. & Sand-Jensen, K., 1993. Seasonal acclimation of eelgrass *Zostera marina* growth to light. *Marine Ecology Progress Series*, **94**, 91-99.
- Peralta, G., Pérez-Lloréns, J.L., Hernández, I. & Vergara, J.J., 2002. Effects of light availability on growth, architecture and nutrient content of the seagrass *Zostera noltii* Hornem. *Journal of Experimental Marine Biology and Ecology*, **269**, 9-26.
- Perkins, E.J., 1988. The impact of suction dredging upon the population of cockles *Cerastoderma edule* in Auchencairn Bay. *Report to the Nature Conservancy Council, South-west Region, Scotland*, no. NC 232 I).
- Philippart, C.J.M., 1994a. Interactions between *Arenicola marina* and *Zostera noltii* on a tidal flat in the Wadden Sea. *Marine Ecology Progress Series*, **111**, 251-257.
- Philippart, C.J.M., 1994b. *Eutrophication as a possible cause of decline in the seagrass Zostera noltii of the Dutch Wadden Sea.* <http://www.nioz.nl/en/deps/mee/katja/seagrass.htm>, 2000-10-23
- Philippart, C.J.M., 1995a. Effect of periphyton grazing by *Hydrobia ulvae* on the growth of *Zostera noltii* on a tidal flat in the Dutch Wadden Sea. *Marine Biology*, **122**, 431-437.
- Philippart, C.J.M., 1995b. Seasonal variation in growth and biomass of an intertidal *Zostera noltii* stand in the Dutch Wadden Sea. *Netherlands Journal of Sea Research*, **33**, 205-218.
- Phillips, R.C., & Menez, E.G., 1988. Seagrasses. *Smithsonian Contributions to the Marine Sciences*, no. 34.
- Plus, M., Deslous-Paoli, J-M., Auby, I. & Dagault, F., 2001. Factors influencing primary production of seagrass beds (*Zostera noltii* Hornem.) in the Thau lagoon (French Mediterranean coast). *Journal of Experimental Marine Biology and Ecology*, **259**, 63-84.
- Rasmussen, E., 1977. The wasting disease of eelgrass (*Zostera marina*) and its effects on environmental factors and fauna. In *Seagrass ecosystems - a scientific perspective*, (ed. C.P. McRoy, & C. Helfferich), pp. 1-51.
- Tubbs, C.R. & Tubbs, J.M., 1982. Brent geese (*Branta bernicla*) and their food in the Solent, southern England. *Biological Conservation*, **23**, 33-54.
- Tubbs, C.R. & Tubbs, J.M., 1983. The distribution of *Zostera* and its exploitation by wildfowl in the Solent, southern England. *Aquatic Botany*, **15**, 223-239.
- Vermaat, J.E. & Verhagen, F.C.A., 1996. Seasonal variation in the intertidal seagrass *Zostera noltii* Hornem.: coupling demographic and physiological patterns. *Aquatic Botany*, **52**, 259-281.
- Vermaat, J.E., Agawin, N.S.R., Fortes, M.D., Uri, J.S., Duarte, C.M., Marbà, N., Enriquez, S. & Vierssen van, W., 1997. The capacity of seagrasses to survive increased turbidity and siltation: the significance of growth form and light use. *Ambio*, **26** (8), 499-504.
- Williams, T.P., Bubb, J.M., & Lester, J.N., 1994. Metal accumulation within salt marsh environments: a review. *Marine Pollution Bulletin*, **28**, 277-290.

Datasets

- Botanical Society of Britain & Ireland, 2018. Other BSBI Scottish data up to 2012. Occurrence dataset: <https://doi.org/10.15468/2dohar> accessed via GBIF.org on 2018-09-25.
- Botanical Society of Britain & Ireland, 2018. Scottish SNH-funded BSBI records. Occurrence dataset: <https://doi.org/10.15468/llasrt> accessed via GBIF.org on 2018-09-25.
- Botanical Society of Britain & Ireland, 2018. Welsh BSBI data (ex-VPDB dataset) at hectad resolution. Occurrence dataset: <https://doi.org/10.15468/rsvnif> accessed via GBIF.org on 2018-09-25.
- Centre for Environmental Data and Recording, 2018. Ulster Museum Marine Surveys of Northern Ireland Coastal Waters. Occurrence dataset <https://www.nmni.com/CEDaR/CEDaR-Centre-for-Environmental-Data-and-Recording.aspx> accessed via NBNAAtlas.org on 2018-09-25.
- Isle of Wight Local Records Centre, 2017. Isle of Wight Notable Species. Occurrence dataset: <https://doi.org/10.15468/sm4ety> accessed via GBIF.org on 2018-09-27.
- Kent Wildlife Trust, 2018. Kent Wildlife Trust Shoresearch Intertidal Survey 2004 onwards. Occurrence dataset: <https://www.kentwildlifetrust.org.uk/> accessed via NBNAAtlas.org on 2018-10-01.
- Manx Biological Recording Partnership, 2017. Isle of Man wildlife records from 01/01/2000 to 13/02/2017. Occurrence dataset: <https://doi.org/10.15468/mopwow> accessed via GBIF.org on 2018-10-01.
- Manx Biological Recording Partnership, 2018. Isle of Man historical wildlife records 1995 to 1999. Occurrence dataset: <https://doi.org/10.15468/lo2tge> accessed via GBIF.org on 2018-10-01.
- National Trust, 2017. National Trust Species Records. Occurrence dataset: <https://doi.org/10.15468/opc6g1> accessed via

GBIF.org on 2018-10-01.

NBN (National Biodiversity Network) Atlas. Available from: <https://www.nbnatlas.org>.

OBIS (Ocean Biogeographic Information System), 2019. Global map of species distribution using gridded data. Available from: Ocean Biogeographic Information System. www.iobis.org. Accessed: 2019-03-21

Royal Botanic Garden Edinburgh, 2018. Royal Botanic Garden Edinburgh Herbarium (E). Occurrence dataset: <https://doi.org/10.15468/ypoair> accessed via GBIF.org on 2018-10-02.

South East Wales Biodiversity Records Centre, 2018. SEWBReC Vascular Plants (South East Wales). Occurrence dataset: <https://doi.org/10.15468/7qjujd> accessed via GBIF.org on 2018-10-02.

Suffolk Biodiversity Information Service., 2017. Suffolk Biodiversity Information Service (SBIS) Dataset. Occurrence dataset: <https://doi.org/10.15468/ab4vwo> accessed via GBIF.org on 2018-10-02.