Saltmarsh (pioneer)

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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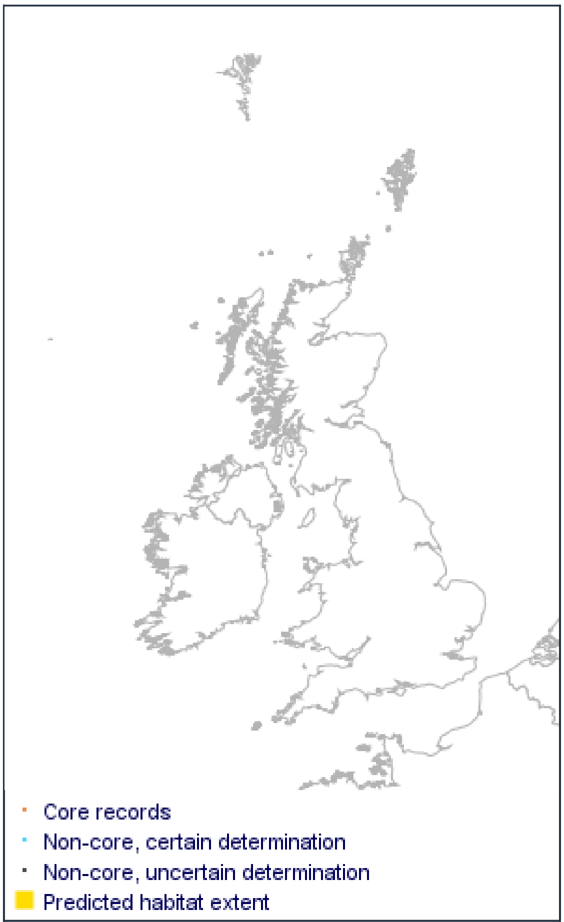
Suaeda maritima and *Spartina salicornia*.
Photographer: Dr Ian Powell



17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Harvey Tyler-Walters **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A2.55	Pioneer saltmarshes
JNCC 2015	LS.LMp.Sm_	Saltmarsh (pioneer)
JNCC 2004	LS.LMp.Sm.Pio	Saltmarsh (pioneer)
1997 Biotope	LS.LMU.Sm	Saltmarsh (low)

Description

Angiosperm-dominated stands of vegetation, occurring on the extreme upper shore of sheltered coasts and periodically covered by high tides. The vegetation develops on a variety of sandy and muddy sediment types and may have admixtures of coarser material. The character of the saltmarsh communities is affected by height up the shore, resulting in a zonation pattern related to the degree or frequency of immersion in seawater. Saltmarsh vegetation is generally well studied; its classification is fully covered by the UK National Vegetation Classification, where 26 types are defined (Rodwell, 2000). Pioneer saltmarsh is represented by 8 of the 26 NVC communities recognised by Rodwell (2000) and are dominated by *Spartina* sp., *Salicornia* spp., *Suaeda maritima*, *Aster* spp. and *Arthrocnemum perenne* communities. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Depth range

Strandline

Additional information

The literature on saltmarsh habitats is extensive and it would be impossible to include all available information in this review. Therefore, the following review is based on more extensive reviews and texts to which the reader is directed for further information (Ranwell, 1972; Long & Mason, 1983; Adam, 1993; Packham & Willis; 1997; Rodwell, 2000).

Listed By

- none -

Further information sources

Search on:

JNCC

Habitat review

Ecology

Ecological and functional relationships

Few grazers feed on the saltmarsh plants directly. In spring and summer*Spartina* sp. are highly productive and in autumn leave die back and decompose on the stalk. Therefore, the majority of *Spartina* sp. productivity, and presumably other vascular plant productivity, enters the food web as detritus. Benthic algae and microphytobenthos play an important role in cycling nutrients, and hundreds of species of bacteria, fungi, and microalgae may be attached to surfaces of vascular plants and sediment. These are grazed by meiofauna (e.g. protozoa, foraminifera, nematodes). There are significant numbers of marine macrofauna species present.

- The majority of saltmarsh insects are sap sucking aphids or chewing grasshoppers, e.g. the saltmarsh aphid, *Sipha littoralis* feeds mainly on *Puccinellia maritima* and *Spartina anglica*, and the aphid *Macrosiphonella asteris* feeds on stems of *Aster tripolium* with lowest salt content, but may not be found in pioneer saltmarsh biotopes.
- The brent goose (*Branta bernicla*) grazes *Puccinellia maritima* and *Aster tripolium* in high marsh at the end of winter. Estimates of the amount of plant material consumed by wildfowl in saltmarsh and seagrass beds range from 1 to 50% (Raffaelli & Hawkins, 1999).
- *Macoma baltica*, *Corophium volutator* and *Arenicola marina* are deposit feeders, while *Nereis diversicolor* and *Nephtys hombergi* act as predators.
- *Hydrobia ulvae* grazes the microflora from sediment grains and epiphytes. Several birds species feeding on intertidal flats probably also feed on adjacent saltmarsh, e.g. shelduck which feed extensively on *Hydrobia ulvae* together with *Macoma baltica* and *Corophium volutator*.
- Gobies e.g. *Pomatoschistus minutus* (sand goby) are significant predators on *Corophium volutator*.

Seasonal and longer term change

In submergent *Spartina -Salicornia* saltmarsh in Norfolk, UK annelid numbers increased in spring and declined in June-July and increased again in late summer (Packham & Willis 1997). The sand goby entered the marsh in early summer, moved away in August -September but was abundant again in autumn. Germination of salt-marsh plants tends to occur in spring, encouraged by low salinities although *Salicornia* spp. can germinate at high salinities. The filamentous green algae *Ulothrix* is found on exposed mud in spring but disappears in summer.

There is a continual change in bird species in the coastal zone. January brings wildfowl back from their annual moult migration e.g. shelduck, wigeon, mallard, teal and pintail. Waders become conspicuous in May e.g. godwits, grey plover, and spotted redshank. Terns, ringed plover, oystercatcher and shelduck breed in June. However, the exact array of species varies between sites depending on the types of coastal habitats and feeding grounds present, disturbance and availability of nesting sites.

Habitat structure and complexity

Pioneer saltmarsh occurs in sheltered, low energy habitats at the top of the intertidal where sediment has built up above mean high water of neap tides (MHWN). The sediment becomes colonized by halophytic vascular plants which themselves stabilize the sediment, slow water movement and promote additional accretion of sediment, until the height of the marsh is only covered by the highest tides. Pioneer saltmarsh communities represent colonizing species early in saltmarsh development (succession) and zonation and occupy a zone between MHWN and mean high water (MHW).

- In areas subject to wave action the saltmarsh may be limited to the highest astronomical tides (HAT) but in very sheltered areas may extend to MHWN. The extent of saltmarsh is affected by topography and may be extensive on flat, gently sloping shores or limited to a few metres on steep shores.
- Sedimentation rates, and hence accretion rates vary between sites e.g. 8 mm/yr. at Scolt Head, east England and 78 mm/yr. in the Dovey, Wales (Packham & Willis, 1997), and is determined by the hydrographic regime, and sediment supply from eroding cliff or riverine sources. Sediment may be bound by mucilaginous diatoms of the microphytobenthos, tubes of burrowing polychaetes, vegetation, or destabilized by bioturbation due to infauna e.g. *Corophium volutator*or *Hydrobia* sp.
- Pioneer saltmarsh communities may be washed away by tides, currents and storms and appear patchy until the vegetation becomes established.
- Saltmarsh are characterized by a network of creeks formed by freshwater runoff and salt pans. Growth of pioneer plants on raised areas concentrates water flow into channels that form deepening creeks as the marsh develops. Depressions surrounded by vegetation (pans), hold water that evaporates after high tide, in many respects, the saltmarsh equivalent of rockpools. However, typically 70% of the surface is dominated by saltmarsh flat (Ranwell, 1972; Long & Mason, 1983; Adam, 1993; Packham & Willis; 1997).
- The substratum varies but contains more silt and clay than underlying intertidal sediment e.g. saltmarsh soil at Bull Island, Dublin Bay was 75% sand whereas at Colne Point, east England it was 5%. The relative composition of sand affects porosity and water holding capacity.
- Organic matter is derived from deposited detritus and particulate matter together with degraded plant material from saltmarsh vegetation. Therefore the organic content increases with time and shore height.
- The high organic content encourages microbial activity, which together with poor oxygen exchange in silty sediments results in anoxic conditions, releasing toxic methane and hydrogen sulphide. Typically, saltmarsh soil has a high salinity, is commonly anaerobic, and has low levels of nitrogen and phosphorus compared to other terrestrial soils.
- *Salicornia* sp. and *Atriplex* sp. dominate around MHWN is presence of wave action but where occasional smothering by marine debris keeps vegetation open. Low water marsh is dominated by *Spartina* sp., *Aster tripolium*, and *Puccinellia phyganodes*.
- Seventy two species of Bryophytes (mosses & liverworts) are found on British saltmarsh, especially *Pottia heimii*.
- Macroalgae may predominate the lower saltmarsh, e.g. dwarf *Fucus vesiculosus* and *Ascophyllum nodosum*; *Pelvetia caniculata*ecad *libera* is found in pans entangled in vascular plant stems, and *Ulva nana* and *Catanella repens* may be epiphytic on vascular plant stems. Filamentous brown algae colonize steep creek banks (e.g. *Vaucheria thuretti*); cyanobacteria may be found amongst vascular plants (e.g. *Calothrix* sp.); exposed mud may be colonized by filamentous green algae e.g. *Ulothrix* (found in spring but disappearing in summer).
- The sediment in saltmarsh of the Stour estuary was found to support the polychaete *Nereis diversicolor*, the oligochaetes *Tubificoides benedini* and *Tubiflex costatus*, the crustacean *Corophium volutator*, and the mud snail *Hydrobia ulvae*. The intertidal

collembolan *Anurida maritima* may be confined to the transition zone from mudflat to marsh.
- Epibenthic fish are restricted to pools and creeks at low tide but may feed over a wider area, including pioneer saltmarsh, at high tide e.g. *Pomatoschistus minutus* (sand goby) and *Gasterosteus aculeatus* (three-spined stickleback).

Productivity

Primary producers include the vascular plants and microalgae and any filamentous algae and macrophytes present. Adam (1993) suggested that algae made an important contribution to net productivity. Saltmarsh is highly productive, although most of the productivity is consumed secondarily. Dead plant material is broken down by bacteria on the surface of the sediment. This increases its food value by degrading cellulose in digestible carbohydrates. The remaining detritus forms the basis of a food chain for a wide variety of organisms and may be a major source of organic carbon for surrounding communities, depending on the hydrographic regime. For example, primary productively for *Spartina*, *Salicornia* and *Limonium* saltmarsh in the UK was estimated to be 400 gC /m^2/ year (Mann, 1982 cited in Raffaelli & Hawkins, 1999).

Recruitment processes

Spartina anglica is a perennial and can spread over large distances by means of fragments carried to new sites with the tide. Gaps in colonies rapidly fill with seedlings once the colony is established, although it produces seed erratically which lose viability if they dry out. *Spartina maritima* however, sets little fertile seed and widely separated clones develop from the occasional fragment and it therefore has a restricted distribution. Plants of the genus *Salicornia*, *Atriplex* and *Suaeda* are annuals with flowers carried in the shoot and extensive seed banks that persist for more than a year. Plants of these species need 2-3 days without flooding to root effectively. Recruitment in infaunal sediment dwelling invertebrates may be patchy and sporadic depending on the hydrographic regime and post-settlement mortality (from scour, smothering and predation).

Time for community to reach maturity

Beeftink (1979) reviewed the effects of disturbance on *Haliminone portulacoides* saltmarsh communities in the Netherlands. After die back of the *Haliminone portulacoides* communities a successional recolonization occurred, beginning with *Suaeda maritima* (and sometimes *Salicornia* sp.) followed by *Aster tripolium*, then *Puccinellia maritima* until *Haliminone portulacoides* returned. The time take for recovery depended on the initial level of disturbance to the *Haliminone portulacoides* community, taking less time after minimal disturbance. For example, *Suaeda maritima* recolonized within a year after waterlogging, and *Suaeda maritima* and *Salicornia europaea* recolonized within three years of chemical destruction of the *Haliminone portulacoides* community.

Additional information

None entered

Preferences & Distribution

Habitat preferences

Depth Range	Strandline

Water clarity preferences	Medium clarity / Medium turbidity, No preference
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Variable (18-40 psu)
Physiographic preferences	Enclosed coast / Embayment
Biological zone preferences	Infralittoral, Supralittoral
Substratum/habitat preferences	Mud, Muddy sand, Sandy mud
Tidal strength preferences	
Wave exposure preferences	Extremely sheltered, Very sheltered
Other preferences	

Additional Information

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

-

Additional information

Saltmarsh communities are generally regarded as species poor habitats. However, this statement generally refers to the vascular plant communities alone. The dynamic and heterogeneous saltmarsh habits and their plant communities support a diverse array of marine and terrestrial invertebrates, microalgae, cyanobacteria, fungi, fish, birds and in some cases mammals (including livestock). For examples of species found in saltmarsh habitats refer to reviews by Long & Mason (1983), Adam (1993) and Packham & Willis (1997) and the references therein.
Saltmarsh habitats support a number of rare or scarce plant species, together with some UK BAP species e.g. the ground beetles *Arnara strenua* and *Anisodactylus poeciloides*, the natterjack toad *Bufo calamita*, eyebrights e.g. *Euphrasia heslop-harrisonii*, and the red data book species *Vertigo angustior*, the narrow mouthed whorl snail (Anon, 1999n).

Sensitivity review

Explanation

Pioneer saltmarsh biotope complex (LMU.Sm) is comprised of 8 recognised plant communities (e.g. LMU.NVC_SM13). Therefore, key and important species have not been suggested in this general review.

Species indicative of sensitivity

Community Importance	Species name	Common Name

Physical Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Substratum Loss	High	High	Moderate	Decline	Very low

Removal of the substratum will remove the vegetation and infauna. Recovery will be dependant on recruitment. Pioneer species such as *Salicornia* sp. and *Aster tripolium* are likely to recover quickly whereas *Spartina* sp. will depend on transport of plant fragments and seed. Infaunal recovery will be dependant on recruitment form neighbouring intertidal populations and may take up to 5 years depending on the species, although mobile species will colonize quickly (e.g. ca I year).

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Smothering	Intermediate	High	Low	Minor decline	Very low

Smothering by 5cm of sediment may cover small plants, removing them from light. However, saltmarsh plants are adapted to accreting environments and may not be adversely affected by smothering for a month, depending on the species and the grain size of the smothering material e.g. die back of *Spartina anglica* in the Solent, southern England was associated with accumulation of very fine sediment. The intolerance of epifaunal burrowers and suspension feeders was higher than deep burrowing siphonate species (Hall, 1994).

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Increase in suspended sediment	High	Moderate	Moderate	Decline	Low

Salt marshes are dependant on suspended sediment to grow (accretion) and vulnerable to erosion, although a dynamic balance or erosion and accretion is probably normal. Die back of *Spartina anglica* in the Solent, southern England was associated with accumulation of very fine sediment, and changes in sediment type may affect saltmarsh communities (Holt *et al.*, 1995). Increased siltation may increase sedimentation rates above growth rates resulting in smothering, whereas decreases siltation rates may reduce the rate of growth of the saltmarsh and subject it to increased erosion. Overall, any activity that changes the sedimentary regime could potentially have marked effects on saltmarsh. Therefore, an intolerance of high and a recoverability of moderate has been suggested (see additional information below).

Decrease in suspended sediment

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Dessication	Intermediate	High	Low	Minor decline	Low

Drought may control the salinity levels and the community in the high marsh. In warm dry summers the marsh become hypersaline, dry out and crack. In the dry summer of 1967, drought on the north Irish coast caused extensive die-back of *Spartina anglica* even though it is tolerant of salinities in excess of normal seawater (Packham & Willis, 1997). Desiccation at the above level is likely to significantly affect epifauna and infauna. An increase in desiccation, equivalent to an increase or decrease of the level on the shore is likely to change the community from pioneer to low-mid saltmarsh or intertidal flat communities or biotopes.

Increase in emergence regime	High	Moderate	Moderate	Decline	Moderate

Decreased emergence, for example due to sea level rise or barrages, may move the high water mark further up shore but this is not possible in the presence of sea defences. The low water mark moves inshore, effectively reducing the area available for invertebrates and feeding of birds and fish, so called 'coastal squeeze'. Resultant increased water depth changes infaunal feeding types and increases area available to predatory fish, and hence the community. Similarly it reduces the area available to shore birds and reduces the carrying capacity of the area for wildfowl. Increased emergence will allow species typical of higher saltmarsh to invade while allowing the pioneer species to colonize further offshore. However, decreased emergence is likely to decrease the extent of the saltmarsh, moving the pioneer community up shore.

Decrease in emergence regime

Increase in water flow rate	High	Moderate	Moderate	Decline	Low

Change in water flow rate and hence the hydrographic regime will change the accretion and erosion rates in the saltmarsh. Increases in water flow rate may erode areas at the face of the raised salt marsh, resulting in a 'cliff' and may undermine the edges of creeks. Recovery will depend the accretion of eroded sediment and subsequent recruitment of the pioneer species (see additional information below).

Decrease in water flow rate

Increase in temperature	Low	Very high	Very Low	No change	Very low

Increases in temperature are likely to result in increased evaporation and desiccation (see above). However, vascular plants are terrestrial in origin and adapted to relatively wider extremes of temperature than intertidal species.

Decrease in temperature

Increase in turbidity	Tolerant	Not relevant	Not relevant	No change	Not relevant

Saltmarsh are accreting habitats and probably turbid. Turbidity reduces the light attenuation through water. However, salt marsh vegetation is emersed for the majority of the tidal cycle and able to photosynthesize.

Decrease in turbidity

Increase in wave exposure	High	Moderate	Moderate	Decline	Low

Change in wave exposure and hence the hydrographic regime will change the accretion and erosion rates in the salt marsh, especially at low water exposed to immersion for longer periods. Increases in wave action may erode areas at the face of the raised salt marsh, resulting in a 'cliff' and may undermine the edges of creeks. Recovery will depend replacement of eroded sediment and the subsequent recruitment of the pioneer species (see additional information below).

Decrease in wave exposure

Noise	High	Very high	Low	Minor decline	High

Disturbance by noise and visual presence of human activities to bird populations are difficult to separate and have been considered together. The level of disturbance is dependant on the species considered. Some species habituate to noise and visual disturbance while others become more nervous. For example, brent geese, redshank, bar-tailed godwit and curlew are more 'nervous' than oyster catcher, turnstone and dunlin. Turnstones will often tolerate one person within 5-10m. However, one person on a tidal flat can cause birds to stop feeding or fly off affecting c. 5 ha for gulls, c.13ha for dunlin, and up to 50 ha for curlew (Smit & Visser, 1993). Goss-Custard & Verboven (1993) report that 20 evenly spaced people could prevent curlew feeding over 1000 ha of estuary. Industrial and urban development may exclude shy species from adjacent tidal flats. Disturbance causes birds to fly away, increasing energy demand and feeding on the flats later or cause them to move to alternative sites. Least human disturbance is likely in winter, however during breeding period for some species and moulting periods of northerly breeding species in late summer and early autumn most recreational activity takes place. Removal of predators may allow some species to dominate, enable recruitment of others and affect the community structure. However, visual or noise disturbance is unlikely to affect epibenthic or infaunal species, therefore although wildfowl may be regarded as highly intolerant, and overall assessment of intermediate is given. Recovery of birds population may be immediate for some species, while shy species may find more isolated sites.

Visual Presence	High	Very high	Low	Minor decline	High

Disturbance by noise and visual presence of human activities to bird populations are difficult to separate and have been considered together (see above).

Abrasion & physical disturbance	Intermediate	High	Low	Minor decline	Very low

Abrasion in saltmarsh biotopes is likely to result from trampling and vehicle use . In coastal plant communities trampling may favour plants with high growth rates, basal meristems, and low growth forms. Low levels of trampling encourage growth and species richness but these fall as trampling increases (Packham & Willis 1997). It is likely that succulents, such as *Salicornia* sp. are intolerant of trampling. Trampling may also affect the substratum, either through destabilization of creek walls and loss of vegetation, or may result in compaction of sediments and reduced aeration. Some plants will be damaged and invertebrates may be displaced but effects are likely to be restricted in area, therefore, an intolerance of intermediate has been recorded.

Displacement	High	Moderate	Moderate	Decline	Low

Once removed vascular plants can not reattach and will be lost. However, *Spartina* sp. can establish colonies from remaining fragments and may recover quickly. Most infaunal species can burrow back into sediment, but may suffer significant predation as a result of being removed from the sediment.

Chemical Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Synthetic compound contamination	High	High	Moderate	Decline	Low

Sheltered, low energy areas in enclosed bays or estuaries act as a sink for sediment and detritus. Low dispersion within these areas also acts as a sink for complex mixtures of pollutants, especially since many become adsorbed onto organic particulates and fine sediments e.g. chlorinated hydrocarbons, DDT (Clark 1997). Therefore the sediments act as a sink for a wide variety of contaminants, many with a long half life in the environment, e.g. PCBs, dieldrins, and pesticides. Some pollutants may bioaccumulate within the food chain, e.g. PCBs and mercury. The sublethal or toxic effects vary with concentration, the bio-availability of the contaminant, and the physiology of the affected organism (Nedwell, 1997 cited in Elliot *et al.*, 1998). Recovery requires dilution, biodegradation or removal of the contaminant from the sediments. Contaminants with long half lives may remain in sediment for decades, at least, in sheltered areas with little dispersion. Intertidal sediments in Southampton Water and the Tees had reduced benthic communities due to contamination with phenols, oil effluent, sulphides and nitrogen compounds (Elliot *et al.*, 1998). *Spartina alterniflora* was found to accumulate high levels of cadmium, lead and zinc in experiments with sewage sludge treatment in the USA (Long & Mason, 1983).

Heavy metal contamination	Intermediate	High	Low	Decline	Low

Flocculation, salinity and pH changes within estuaries, in particular result in the preferential precipitation of some heavy metals, e.g. Fe and Cu (Bryan, 1984). As above sediments act as sinks for contaminants including heavy metals. *Spartina alterniflora* was found to accumulate high levels of cadmium, lead and zinc in experiments with sewage sludge treatment in the USA (Long & Mason, 1983). Packham & Willis (1997) note that acute toxicity to heavy metals has not been reported in saltmarsh plants. However, different members of the community are likely to vary in their intolerance to heavy metal pollution.

Hydrocarbon contamination	High	Low	High	Decline	Moderate

Salt marshes are very intolerant of oil spills since they trap sediments, adsorb oils, and occur in sheltered environments where the oils persist (Holt *et al.*, 1997). The effect of spills depends on the type of oil and its extent with lighter oils being the most toxic. Heavy oils tend to cause death by smothering (Baker, 1979). In successive experimental oilings Baker (1979) demonstrated the 5 levels of intolerance to Kuwait crude oil, for example:

- very susceptible; *Salicornia* sp., *Suaeda maritima* and seedling of all species were quickly killed by a single spill;
- intermediate; species that recovered well from up to four spills but rapidly succumbed if further oiled, e.g. *Puccinellia maritima*, *Spartina anglica* and *Festuca rubra*;
- resistant due to underground storage organs e.g. *Armeria maritima*, *Plantago maritima* and *Triglochin maritima*.

Annual species are most intolerant and are either killed or their reproduction is repaired. Shallow rooted *Salicornia* sp. and *Suaeda* sp. are susceptible since they have few food reserves, whereas plants with underground storage organs are resistant, e.g. *Armeria maritima* and *Plantago maritima*. Experiments show that most species succumbed after more than four oilings and 8 -12 oiling resulted in significant die back (Baker, 1979). Chronic hydrocarbon pollution may also greatly affect saltmarsh communities. Dicks & Hartley (1982) reported that discharge of refinery effluent (containing oils and other chemicals), together with small accidental discharges from Fawley terminal, Southampton (1953-1970) caused loss of vegetation from a large area of the adjacent saltmarsh (Holt *et al.*, 1995). Trampling and disturbance caused by clean up operations may increase the levels of damage (Holt *et al.*, 1995).
Long term chronic petrochemical effluent also affects the infauna (McLusky, 1982). Studies of

intertidal mudflats in the Forth estuary contaminated by petroleum effluent discharge showed that *Hydrobia ulvae*, *Macoma baltica* and *Hediste diversicolor* survived at low abundance in severely polluted areas of low oxygen content, and increased in abundance in polluted areas while oligochaetes and spionids were able to colonize. *Cerastoderma edule*, *Corophium volutator* and *Mya arenaria* were more intolerant being restricted to areas of moderate pollution (McLusky, 1982). No information concerning insect fauna was found, however a proportion of the fauna is likely to be adversely affect or leave the saltmarsh. The sensitivity of bird species is well known.

Overall, saltmarsh habitats are considered to by highly sensitive to oil spills (Gundlach & Hayes, 1978; Holt *et al.*, 1995; Packham & Willis, 1997). Therefore, an intolerance of high has been recorded.

Recovery depends on the retention of oil within the saltmarsh, e.g. after the *Amoco Cadiz* spill some areas of saltmarsh still had oily footprints 5 years later (Holt *et al.*, 1995). Similarly Baker (1979) reported that the effects of oiling were still apparent 10 years after oiling. Dicks & Hartley (1982) reported that reduction of hydrocarbons content and discharge rate took place between 1970 and 1975 in the Fawley marsh. By 1980 vegetation had recolonized much of the area, pioneer species such as *Salicornia* sp. and *Aster tripolium* recolonized quickly followed, slowly by *Spartina anglica* but the sediment remained contaminated and supported an impoverished fauna, which rare oligochaetes and reduced numbers of *Nereis diversicolor*. Dicks & Levell (1989) reported that annual species (e.g. *Salicornia* sp. and Suaeda maritima) and the perennial Spartina anglica had colonized most of the previously denuded area by 1987, although Spartina anglica recovery was aided by transplantation. Dicks & Levell (1989) suggested that areas recolonized by Spartina anglica in 1977 had begun to resemble healthy marshes by 1987 (10 years), although recovery of the whole area would probably take another 5-10 years. Seneca & Broome (1982; cited in Holt *et al.*, 1995) suggested that recovery from the *Amoco Cadiz* spill would have taken 5-10 years without restoration. Overall, the above evidence suggests that annual species would probably recover within a few years while perennial species such as Spartina anglica would take between 10 to 20 years. Therefore, a recoverability of low has been recorded.

Radionuclide contamination Insufficient information Not relevant

Insufficient information

Changes in nutrient levels Intermediate High Low Minor decline Very low

Moderate enrichment with nutrients may be beneficial to both plant and infaunal communities. Plots of salt marsh treated with sewage sludge in Massachusetts, USA, stimulated growth of *Spartina alterniflora* which eliminated other plants from the area (Long & Mason 1983).

Increase in salinity Low Very high Very Low No change Very low

Saltmarsh plants live inhabit an environment hostile to terrestrial plants and are tolerant of fluctuating salinity, especially at the lower shore.

Decrease in salinity

Changes in oxygenation Low Very high Very Low Minor decline Low

Vascular plants may be not sensitive to deoxygenation since photosynthesis liberates oxygen, they are uncovered for the majority of the tidal cycle, and in some species, e.g. *Spartina alterniflora* air spaces in the leaf sheaths aid gas transport to the roots. However, other members of the community, such as infauna are intolerant of deoxygenation.

Biological Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Introduction of microbial pathogens/parasites				Insufficient information	Not relevant

Although pathogens of *Spartina anglica* are known they have not been implicated in die backs. No information on pathogens of other important species was found.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Introduction of non-native species	Intermediate	High	Low	Minor decline	Very low

Introduction of North American cord grass *Spartina alterniflora* to stabilize and reclaim high intertidal mudflats has significantly altered UK saltmarsh. *Spartina alterniflora* hybridized with native *Spartina maritima* producing an infertile hybrid (*Spartina townsendii*) which gave rise to fertile *Spartina anglica*. *Spartina anglica* is fast growing and aggressive and has colonized extensive areas of intertidal mudflats, increasing the area of saltmarsh in the UK but reducing intertidal feeding grounds for shorebirds. The success of *Spartina anglica* may dominate the community to the detriment of other species reducing species richness (Eno *et al.* 1997).

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Extraction of this species	Intermediate	High	Low	No change	Very low

Saltmarsh is subject to grazing in the UK. Grazing prevents invasion of the upper saltmarsh by scrub species. Grazing by livestock causes trampling and introduces nutrients (faeces). *Salicornia europaea*, *Puccinellia maritima* and *Armeria maritima* are favoured by grazing while *Spartina anglica* and *Limonium vulgare* are harmed (Long & Mason 1983). Grazing favours prostrate plants over tall plants and increases species richness. Saltmarsh are also grazed by brent geese and wigeon. Grazing also slows floral succession. Overall intolerance has been assessed as intermediate with a high recovery.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Extraction of other species	Intermediate	High	Low	No change	Very low

Additional information

Recoverability

Pioneer species such as *Salicornia* sp. and *Aster tripolium* are likely to recover quickly whereas *Spartina* sp. will depend on transport of plant fragments and seed. For example, *Suaeda maritima* recolonized within a year after water-logging, and *Suaeda maritima* and *Salicornia europaea* recolonized within three years of chemical destruction of the *Haliminone portulacoides* community. The time take for recovery depended on the initial level of disturbance to the *Haliminone portulacoides* community, taking less time after minimal disturbance (Beeftink, 1979). Infaunal recovery will be dependant on recruitment form neighbouring intertidal populations and may take up to 5 years depending on the species, although mobile species will colonize quickly (e.g. ca I year). Overall, pioneer saltmarsh will probably recover within less than 5 years of disturbance. Where the sediment has been eroded, recovery will probably be delayed until the sediment levels has built up again.

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