Ruppia maritima in reduced salinity infralittoral muddy sand

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

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2015-08-21

A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

This review can be cited as:
Tyler-Walters, H. & d'Avack, E.A.S., 2015. [Ruppia maritima] in reduced salinity infralittoral muddy sand. 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/marlinhab.266.1

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***Ruppia maritima* in reduced salinity infralittoral muddy sand.**
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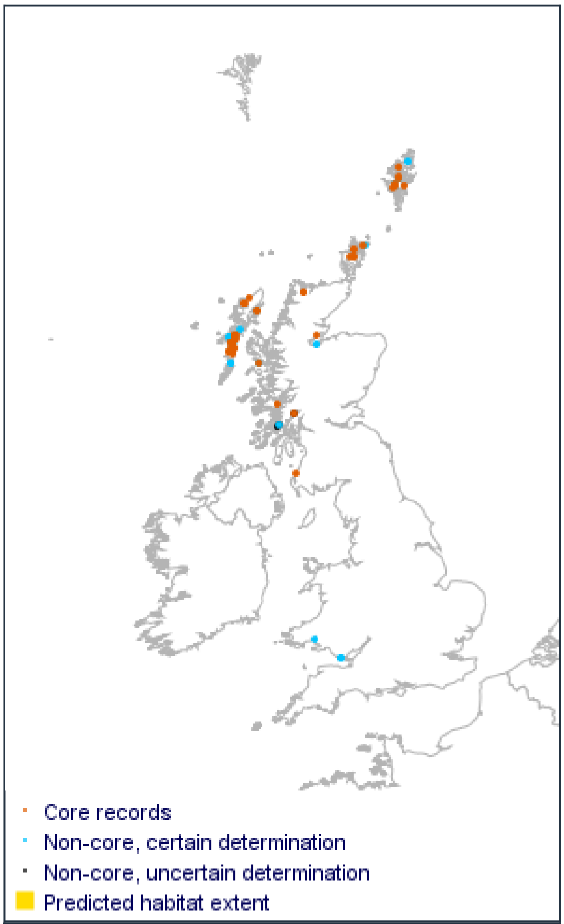

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Harvey Tyler-Walters & Emilia d'Avack **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A5.5343	*Ruppia maritima* in reduced salinity infralittoral muddy sand
JNCC 2015	SS.SMp.SSgr.Rup	*Ruppia maritima* in reduced salinity infralittoral muddy sand
JNCC 2004	SS.SMp.SSgr.Rup	*Ruppia maritima* in reduced salinity infralittoral muddy sand
1997 Biotope	SS.IMS.Sgr.Rup	*Ruppia maritima* in reduced salinity infralittoral muddy sand

Description

In sheltered brackish muddy sand and mud, beds of *Ruppia maritima* and more rarely *Ruppia cirrhosa* (syn. *Ruppia spiralis*) may occur. These beds may be populated by fish such as *Gasterosteus aculeatus* and *Spinachia spinachia* which are less common on filamentous algal-dominated sediments. Seaweeds such as *Chaetomorpha* spp., *Ulva* spp., *Cladophora* spp., and *Chorda filum* are also often present in addition to occasional fucoids. In some cases the stoneworts L*amprothamnium papulosum* and *Chara aspera* occur. Infaunal and epifaunal species may include mysid crustacea, the polychaete *Arenicola marina*, the gastropod *Hydrobia ulvae*, the amphipod *Corophium volutator* and oligochaetes such as *Heterochaeta costata*. In some areas *Zostera marina* may also be interspersed with the *Ruppia* beds (Connor *et al.*, 2004).

Depth range

0-5 m

Additional information

Little information concerning the ecology of *Ruppia* sp. beds in the United Kingdom was found. Therefore, this review is based on more detailed reviews of *Ruppia* dominated communities in western Europe and North America (Verhoeven, 1979, 1980a&b; Kantrud, 1991). *Ruppia* is a taxonomically difficult genus (Preston, 1995) and several species and their varieties have been used. In the following review, therefore, the species *Ruppia maritima* is used where specific information has been given, otherwise the genus *Ruppia* alone is used.

Listed By

- none -

Further information sources

Search on:

JNCC

Habitat review

Ecology

Ecological and functional relationships

The rhizomes and roots of *Ruppia maritima* help to stabilize, and oxygenate, the sediment surface, while the stems and leaves provide additional substratum for a variety of algae and invertebrates. Although the functional groups within the ecosystem probably remain fairly constant the abundance and diversity of species within each group varies with the habitat, especially the salinity regime (e.g. Verhoeven & van Vierssen, 1978).

- *Ruppia maritima* and *Ruppia cirrhosa* provide primary production and substratum within the biotope. Few organisms, except wildfowl, feed on the *Ruppia* spp. directly, however, decomposition of leaves and stems, especially in autumn and winter, support a detrital food chain within the biotope and probably also provide primary productivity to deeper water and drift line communities (Verhoeven & van Vierssen, 1978; Zieman *et al.*, 1984; Kantrud, 1991).
- Additional, primary productivity is provided by microbial (e.g. diatoms) and macroalgal epiphytes growing on the leaves of *Ruppia* spp., and a floating mat of filamentous algae (e.g. *Chaetomorpha* sp. and *Cladophora* spp.) and, when present, stoneworts (e.g. *Chara aspera* and *Lamprothamnium papulosum*).
- *Ruppia* spp. leaves may be used as substratum by algal epiphytes as above and faunal epiphytes such as bryozoans and hydroids (e.g. *Einhornia crustulenta*, *Conopeum seurati*, and *Cordylophora caspia*).
- The leaves of *Ruppia* spp. and the algal mats may provide temporary substratum for juvenile anemones and bivalves (e.g. *Anemonia sulcata*, *Mytilus edulis*, *Cerastoderma glaucum*) and the larvae and pupae of aquatic insects (e.g. the shore fly, *Ephydra riparia*) (Verhoeven & van Vierssen, 1978; Verhoeven 1980a; Boström & Bonsdorf, 2000). Aquatic insects probably utilize any available aquatic macrophytes as substratum.
- The epiphytes and algal mats may be grazed by gastropods (e.g. *Rissoa* spp., *Hydrobia* spp. or *Potamopyrgus* spp.), amphipods (e.g. *Gammarus* spp.) and isopods (e.g. *Jaera* spp., and *Idotea* spp.) and probably mysids (e.g. *Neomysis integer*).
- Verhoeven & van Vierssen (1978) and Verhoeven (1980b) suggested that isopods and amphipods may feed directly on *Ruppia* spp., however, their most important role in the food chain was the breaking down of decomposing leaves into fine particles of detritus suitable for suspension and deposit feeders in the detrital food chain.
- Suspension feeders filter both phytoplankton and detritus (organic particulates), for example *Corophium* spp., *Cerastoderma glaucum*, *Mya arenaria*, hydroids, bryozoans, and polychaetes (*Hediste diversicolor*, *Polydora* spp.).
- Surface and infaunal deposit feeders include polychaetes (e.g. *Arenicola marina*, *Manayunkia aestuarina* and *Pygospio elegans*), amphipods (e.g. *Corophium volutator*), bivalves (e.g. *Macoma baltica*), and chironomid larvae.
- Small invertebrates are preyed on by small mobile predators that use the *Ruppia* beds for shelter, for examples insect larvae, mysids, shrimp and sticklebacks (e.g. *Gasterosteus aculeatus* and *Spinachia spinachia*).
- Generalist predators use, but are not closely associated with, the *Ruppia* beds, e.g. the shore crab *Carcinus maenas*, the eel *Anguilla anguilla*, and the goby *Pomatoschistus microps*.
- Several species of wildfowl feed directly on *Ruppia* spp., although the exact species will vary with location, season and salinity, e.g. the tufted duck *Aythya fuligula*, the coot *Fulica*

atra, the wigeon *Anas penelope*, the mute swan *Cygnus olor*.
- Mysids, shrimp and crabs probably act as scavengers within this biotope.

Detailed lists of species and their position within the habitat for several locations in western Europe (Finland, the Netherlands, and France) are given by Verhoeven and his co-author (Verhoeven & van Vierssen, 1978; Verhoeven, 1979, 1980a, b).

Seasonal and longer term change

Ruppia maritima is thought to be an annual while *Ruppia cirrhosa* is perennial (see recruitment) (Verhoeven & van Vierssen, 1978). Annual *Ruppia* species die back complete in winter, overwinter primarily as seed (druplets), that germinate in April (early spring) (Verhoeven & van Vierssen, 1978; Kantrup, 1991). Perennial species overwinter as leaf bearing rhizomes that bud in early spring with occasional development from seed (Verhoeven & van Vierssen, 1978; Kantrup, 1991). Seasonal change includes:

- in early spring (April-May) *Ruppia* species grow rapidly, annual species producing a more luxuriant growth than the perennial species;
- *Ruppia* species produce their greatest biomass by August-September;
- where *Ruppia* forms mixed stands with the sago pondweed *Potamogeton pectinatus*, the pondweed may become dominant by June-July, with *Ruppia* species dominating by August-September;
- *Ruppia* spp. flowers about 5-6 weeks after the onset of spring growth, with pollination occurring about 1-2 weeks later;
- epiphytic microflora (diatoms and algae) steadily colonize the plants during the growing season, and epiphytes cover the plant entirely by autumn;
- wildfowl graze the beds throughout the year, the exact species depending on season, and
- most of the plant material dies in late summer (September) and is removed by autumn winds and resultant wave action, and may form floating plant masses or drift algae and hence support a greater abundance of detritivores.

Ruppia spp. beds inhabiting temporary pools or ditches or other ephemeral habitats may dry out during the summer months and be killed. However, such harsh conditions favour annuals that produce large amounts of seed. Long-term changes in the salinity regime are likely to result in changes in the abundance of *Ruppia* sp. and the associated species; e.g. an long-term decrease in salinity may favour the growth of the sago pondweed *Potamogeton pectinatus*, however an increase in salinity may favour *Ruppia cirrhosa*.

Habitat structure and complexity

The leaves and stems of *Ruppia* spp. provide substratum and refuge for several species, while the rhizome and root system stabilize the sediment, and the transport of oxygen from the leaves to the roots oxygenates the sediment in the vicinity of the roots (the rhizophere) changing the local redox potential, sediment chemistry and oxygen levels. In low salinities *Ruppia* spp. forms mixed stands with other macrophytes such as *Potamogeton pectinatus* or *Zannichellia* spp. whereas in variable to fully saline water it may form mixed stands with *Zostera* spp. and contain more estuarine or fully marine species. Hypersaline conditions may favour *Ruppia cirrhosa*, which tolerates up to ca 108 psu over *Ruppia maritima* (Verhoeven, 1979). Species diversity varies with salinity, being maximum in near full seawater or freshwater conditions but reaching a minimum in the physiologically harsh brackish conditions most favoured by *Ruppia* spp. *Ruppia* spp. inhabit a variety of salinity regimes and varied habitats from near saline estuaries, to brackish ditches and man-made channels to saltmarsh and wetlands, including both long-term and temporary pools, therefore habitat complexity and species composition can vary markedly. However, Verhoeven and his co-author recognised the following elements of the community:

- the *Ruppia* spp. and other associated aquatic macrophytes or macroalgae;
- mats of filamentous algae, e.g. *Chaetomorpha* spp., *Cladophora* spp., and *Ulva* spp., that harbour high densities of invertebrates e.g. Chironomid larvae, amphipods, copepods and juvenile bivalves (Verhoeven & van Vierssen, 1978; Verhoeven 1980a; Boström & Bonsdorf, 2000);
- epiphytic species attached to the plants e.g. diatoms, filamentous diatoms, hydroids, bryozoans;
- temporary epiphytic species, e.g. larval or juvenile anemone, bivalves, and aquatic insects;
- species depositing eggs on *Ruppia* spp. and other macrophytes, e.g. insects, hydrobids, and some fish;
- species living in tubes attached to plants, e.g. the polychaetes *Polydora ligni* and *Spirorbis spirorbis*, and the amphipod *Corophium volutator*;
- species creeping over plants and other hard substrata but not the sediment, e.g. amphipods, isopods, gastropods, and insect larvae;
- species creeping over plants and the sediment bottom, e.g. *Hydrobia* spp. and *Potamopyrgus* spp.;
- benthic infauna, e.g. the oligochaete *Tubifex* spp., polychaetes *Hediste diversicolor*, *Arenicola marina* and *Manayunkia aestuarina*, the amphipod *Corophium volutator*, bivalves *Cerastoderma glaucum*, *Macoma baltica* and *Mya arenaria* and chironomids;
- mobile species in the vegetation canopy, e.g. sticklebacks and pipefish, and
- mobile species occurring within the vegetation and the surrounding area, e.g. shrimps, crabs, mysids, gobies, eels and flatfish.

Where the *Ruppia* beds accumulate sediment and/or lie adjacent to areas that dry out, the *Ruppia* beds may be associated with a succession of terrestrial saltmarsh or marsh plants, e.g. reeds and sedges, forming a hydrosere. The reader is directed to Rodwell (2000) for further information on saltmarsh communities and Rodwell (1995) for further information on aquatic plant communities.

Productivity

Primary productivity

Verhoeven (1980b) suggested that under ideal conditions the largest possible standing crop of *Ruppia* spp. in European waters was about 300 g dry weight /m2;, which was low to moderately productive when compared to marine seagrass or freshwater aquatic plant communities. Verhoeven (1980b) reported values of productivity between 9 -290 g ash weight /m2; in terms of biomass in European sites. Verhoeven (1980b) estimated a minimum annual productivity of 6-15 g C /m2; for *Ruppia cirrhosa* beds in the Camargue lagoons, France and 15-20 g C/m2; for *Ruppia* spp. beds in the Netherlands. In both cases the *Ruppia* spp. productivity was lower than the local phytoplankton productivity.

Ruppia spp. primary productivity is reduced by excessive turbidity, competition (probably for light) with other aquatic plants, algae and phytoplankton, Excessive wave action or water depth (Kantrud, 1991). Filamentous algae and epiphytes inhibit *Ruppia* productivity by shading and by entanglement; increasing the plants sensitivity to wave action. However, algal mats may also shade and reduce epiphytic microflora on the *Ruppia* leaves. Epiphytes reduce Ruppia productivity by shading, competing for nutrients and by interfering with exchange of gases and nutrients across the leaves of *Ruppia* spp., although Verhoeven (1980b) concluded that under eutrophic conditions inhibition by epiphytes was minor compared to the effects of shading and increased turbidity caused by phytoplankton blooms.

Secondary productivity
Fredette *et al*., (1990) estimated that *Zostera* spp. and *Ruppia* spp. seagrass beds supported about 200 g dry weight /m2; /yr. of invertebrate (primarily isopods, amphipods and crabs) secondary productivity, roughly equivalent to 55.9 tonnes of invertebrate production over a year in a 140 ha bed, although they considered their value to be an underestimate. Verhoeven (1980a) reported up to 43,800 invertebrates /m2; (biomass up to 22.9 g ash-free weight /m2;) in *Ruppia* dominated communities, although only 15 of 75 species were closely associated and two species dominated (Verhoeven, 1980a; Kantrup, 1991). Further secondary production is generated through the detrital food chain. About 44% of the autumn decrease in *Ruppia cirrhosa* biomass was due to leaching and decomposition, while the remainder was taken by wildfowl and invertebrates (Verhoeven, 1978; Kantrup, 1991). In experiments, grazing by macro-invertebrates (*Gammarus* spp. and *Sphaeroma* spp.) reduced leaves and shoots of *Ruppia cirrhosa* to particles less than 1mm in 180days (Kantrup, 1991). Verhoeven (1980b) suggested that 90% of the plant material produced in *Ruppia* beds was decomposed and most mineralised (converted to available inorganic nutrient) within the following year.

Recruitment processes

Ruppia maritima is thought to be an annual while *Ruppia cirrhosa* is perennial (Verhoeven & van Vierssen, 1978), however, Kantrup (1991) reported that *Ruppia maritima* could also grow from overwintering rhizomes. *Ruppia* species die back completely in winter, overwinter primarily as seed (druplets), that germinate in April (early spring) (Verhoeven & van Vierssen, 1978; Kantrup, 1991). Perennial species overwinter as leaf bearing rhizomes that bud in early spring with occasional development from seed (Verhoeven & van Vierssen, 1978; Kantrup, 1991). Annual species of *Ruppia* exhibit high fecundity, rapid development, early maturity and the production in a large amount of seed, and are able to survive in more ephemeral habitats. *Ruppia maritima* produces enormous numbers of seeds about two weeks after flowering (June -September), since the flowers are held underwater, where pollination is more efficient. Reproduction occurs in a temperature range of 15-19 °C but decreases above 30 °C. Seeds or duplets can remain viable in the sediment for up to 3 years (Verhoeven & van Vierssen, 1978; Verhoeven, 1979; Kantrup, 1991).

Seed germinate in a wide variety of temperatures and salinity. For example, in Europe *Ruppia maritima* seeds began to germinate when the water temperature exceeded a minimum/maximum interval of 10/15 °C, and mainly between 15-30 °C. Prior desiccation may stimulate germination. Seeds will germinate in as little as 5-10cm of water in culture, although seed production is reduced in shallow waters (Kantrup, 1991). The effect of salinity on germination is temperature dependant. For example, *Ruppia maritima* seeds germinate well at 43.4 psu at 28°C but germination rates is lower at high temperatures and low salinities (<3.5psu) than at low temperatures and salinities up to 26 psu (Kantrup, 1991). Germination may also be affected by oxygen levels and seeds in poorly oxygenated sediments lie dormant until the next year (Kantrup, 1991).

Ruppia maritima can also colonize by rhizomes. overwintering rhizomes bud in early spring, at about the same time as germination, probably in response to temperature (Kantrup, 1991). overwintering rhizomes is of greater importance than seed set in perennials such as *Ruppia cirrhosa*. In perennials the pollination occurs at the water interface, which is less efficient than underwater, and their allocation to reproductive shoots is less than to vegetative production. Orth & Moore (1982) reported that recolonization of sediment denuded of *Ruppia* spp. by a boat propeller occurred at about 0.25 m/yr.

Ruppia species distribution is affected by the isolated nature of their habitats (e.g. lagoons) and their ability to disperse. Seeds and rhizomes can be transported by currents attached to floating detached plant material. After desiccation, dried plants and attached seed can be transported considerable distances by the wind. A proportion of the seed consumed by wildfowl pass through the birds unharmed, therefore, wildfowl could potentially transport seed considerable distances. For example, 30% of the freshwater eelgrass *Naja marina* seeds fed to ducks in Japan survived and successfully germinated after passage through their alimentary canals and could be potentially transported 100-200 km (Fisherman & Orth 1996). Verhoeven (1979) noted that *Ruppia maritima* produces large amount of seed and was the most cosmopolitan *Ruppia* species, suggesting the potential for wide dispersal.

However, competition with infauna such as *Hediste diversicolor* or *Arenicola marina* have been suggested to hamper potential recruitment in *Zostera noltei* (see review) (Hughes *et al.*, 2000; Philippart, 1994a). Similarly, *Corophium volutator* has been reported to inhibit colonization of mud by *Salicornia* sp. (Hughes *et al.*, 2000). Therefore, the above infaunal species could potentially inhibit recruitment in *Ruppia* spp.

The microalgae and filamentous macroalgae found within the biotope are widespread and ubiquitous, producing numerous spores, and can colonize rapidly. Similarly, bryozoans and hydroids probably produce numerous but short lived pelagic larvae, so that local recruitment from adjacent populations is probably rapid.

Boström & Bonsdorff (2000) examined the colonization of artificial seagrass and *Ruppia maritima* beds by invertebrates. They reported colonization by abundant nematodes, oligochaetes, chironomids, copepods, juvenile *Macoma baltica* and the polychaete *Pygospio elegans* within 33-43 days. Disturbance by strong winds after 43 days resulted in a marked increase in the abundance of species by day 57, except for *Pygospio elegans*. They noted that settlement of pelagic larvae was less important than bedload transport, resuspension and passive rafting of juveniles from the surrounding area in colonization of their artificial habitats. Other polychaetes, such as *Arenicola marina* do not possess a pelagic larvae, but migrate as juveniles and can swim as adults. Recolonization in *Arenicola marina* is thought to be rapid where adjacent populations are present, although recolonization may take longer in isolated populations.

The sticklebacks *Gasterosteus aculeatus* and *Spinachia spinachia* are associated with *Ruppia* beds. In both species the males set up a territory and build nests, in which the female lays eggs that are subsequently fertilized and guarded by the males (Fishbase, 2000). The abundance of vegetation provided by the *Ruppia* bed and its associated algal mats probably provides nesting material for the males and a refuge for developing juveniles. While associated with this biotope, sticklebacks are mobile species capable of colonizing the habitat from adjacent areas or the open sea.

Time for community to reach maturity

Ruppia vegetation dies back in autumn and winter, and overwinters either as seed or rhizome, only to germinate or bud in early spring. Therefore, the *Ruppia* bed and its associated community (except the infauna) develops annually. In subtropical climates wintering waterfowl were reported to consume entire stands of *Ruppia* spp., which re-established within weeks in optimal conditions

(Kantrup, 1991). However, if the rhizomes and seed bank is removed community developed may be prolonged.

Ruppia spp. seed and rhizomes can be transported considerable distances by wildfowl or by water currents and wind (when dry). Floating fragments of *Ruppia* spp. grow roots freely, sink and attach to the bottom. For example, Orth & Moore (1982; cited in Kantrup, 1991) reported that sediments denuded by a boat propeller were recolonized at about 0.25m /year. However, little other evidence of colonization rates was found.

Community development will depend on the time taken for *Ruppia* propagules to reach the available habitat. Once rhizomes or seed arrive in the habitat recovery may take several years. In areas connected by water flow or regularly frequented by wildfowl recovery will take many years, but in isolated area habitat recovery may be prolonged, possibly taking up to 5-10 years.

The benthic infauna probably colonizes the associated sediment more slowly but still relatively rapidly. For example, Broström & Bonsdorff (2000) found that abundant infauna colonized artificial seagrass and *Ruppia maritima* habitats within 33 - 57 days (1-2 months). Few species found in *Ruppia* dominated communities are associated with *Ruppia* spp. alone (Verhoeven & van Vierssen, 1978; Verhoeven, 1980a) and most probably colonize the vegetation from the surrounding habitats.

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m
Water clarity preferences	High clarity / Low turbidity
Limiting Nutrients	Manganese, Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Reduced (18-30 psu)
Physiographic preferences	
Biological zone preferences	
Substratum/habitat preferences	Mud, Mud and sandy mud, Muddy sand
Tidal strength preferences	Very Weak (negligible)
Wave exposure preferences	Extremely sheltered
Other preferences	See additional information.

Additional Information

Distribution
Ruppia communities were reported as uncommon 1997 habitat classification (Connor *et al.*, 1997a). More records appear in the 2004 classification (Connor *et al.*, 2004) but numerous records are given, as NVC SM2, by Rodwell (2000).

Habitat preferences

- Wave sheltered soft sediments with weak tidal streams.
- *Ruppia* spp. occur at depths between 0-4.5m depending on turbidity and the tendency for the substratum to be re-suspended, i.e. only occurring at shallow depths (<1.5m) on fine, clay sediments but 2.0m or more on sand or shell substratum.
- *Ruppia* spp. require high levels of light when compared to eelgrass, and therefore, require clear water, e.g. turbidities <25-55 ppm suspended sediment were recommended for wetland management of *Ruppia* beds while *Ruppia* spp. have been reported in waters with 17.5-42.5 ppm suspended sediment.
- *Ruppia* spp. survive water temperatures of 0 -38°C but grow exponentially between 10-30°C.
- *Ruppia* spp. tolerate the widest range of salinities of any aquatic angiosperm and *Ruppia maritima* can occur in waters of 0.6 to 390g /l dissolved solids but grows best in culture between 4.7 -22.6 psu.
- *Ruppia* spp. occur in water of pH 6.0 -10.4 but may have an affinity for waters of pH 7.7 -9.4.

Data from Verhoeven (1979) and Kantrup (1991).

Species composition

Species found especially in this biotope

- *Chara aspera*
- *Gasterosteus aculeatus*
- *Lamprothamnium papulosum*
- *Ruppia cirrhosa*
- *Ruppia maritima*
- *Spinachia spinachia*

Rare or scarce species associated with this biotope

- *Chara aspera*
- *Lamprothamnium papulosum*
- *Ruppia cirrhosa*

Additional information

A large number of species have been identified within *Ruppia* dominated communities. For example, the MNCR recorded 207 species within recorded of the IMS.Rup biotope (JNCC, 1999), however, this number was summed over all records of the biotope. Verhoeven (1980a) recorded between 5-36 species within *Ruppia* communities, which was low when compared to freshwater aquatic plant or marine seagrass communities (Verhoeven, 1980a, Table X). Verhoeven (1980a) concluded that the relative low species richness of *Ruppia* dominated communities was due to the physiological stress of brackish waters, the simplicity of the community structure and the dynamic, seasonal variation in *Ruppia* beds. Verhoeven (1980a) also noted that most species recorded within the community are not closely associated with *Ruppia* itself, but are generalist euryhaline species capable of utilizing other substrata, e.g. he noted that only 15 of ca 60 species recorded were directly dependant on the aquatic vegetation in the *Ruppia* communities studied. However, Verhoeven (1980a) was able to identify 7 *Ruppia* dominated communities (biocoenoses) within northwest Europe.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Ruppia maritima is the main species creating this habitat as removing *Ruppia* plants would result in the disappearance of this biotope. Although a wide range of species are associated with *Ruppia* beds which provide habitat and food resources, these species occur in a range of other biotopes and were therefore not considered by d'Avack *et al.* (2014) to be species characterizing the sensitivity of this biotope. *Ruppia maritima* is not dependent on associated species to create or modify habitat, provide food or other resources. The sensitivity assessments are thus based on *Ruppia maritima* alone and do not consider the sensitivity of associated species that may living in or around seagrass beds. Effects on other component of the community will however be reported where relevant.

Ruppia maritima is not a true seagrass. Although often found with seagrasses, *Ruppia maritima*, also known as wigeon grass or tassel pondweed, is not a true marine plant but considered a freshwater species with a pronounced salinity tolerance (Zieman, 1982). Nevertheless, *Ruppia maritima* beds display similar sensitivities towards pressures as seagrass beds, depending on the position of the habitat on the shore or the sediment type (d'Avack et al., 2014).

Resilience and recovery rates of habitat

Zieman *et al.* (1984) noted that the recovery of seagrass ecosystems depended primarily of the extent or magnitude of damage to the sediments, i.e. the rhizome and root system. This is probably also true of *Ruppia* dominated communities. Where, the rhizomes remain, recovery is likely to be rapid. For example, in subtropical climates wintering waterfowl were reported to consume entire stands of *Ruppia* spp., which re-established within weeks in optimal conditions (Kantrup, 1991). *Ruppia* spp., either annuals or perennials annually die back only to regrow from seed and or overwintering rhizome the following year. Seed survive in sediment for up to three years and germinate as long as they are not buried by more than 10 cm of sediment (Kantrup, 1991). Therefore, if a proportion of the rhizomes or seed bank remains, recovery is likely to be rapid, probably taking a single good growing season or several years in less optimal conditions.

Ruppia vegetation dies back in autumn and winter, and overwinters either as seed or rhizome, only to germinate or bud in early spring (see recruitment processes above). Therefore, *Ruppia* bed and its associated community (except the infauna) develops annually. Micro and macroalgae are ubiquitous and produce numerous spores, while other invertebrates colonize the developing *Ruppia* spp. from adjacent areas, probably through settlement of pelagic larvae but more importantly passive and active migration by juveniles (Broström & Bonsdorff, 2000). For example, the artificial seagrass habitats tested by Broström & Bonsdorff (2000) were colonized by large numbers of a variety of invertebrates with 57 days (ca 2 months).

If the rhizomes and seed bank is removed recovery may be prolonged. *Ruppia* spp. seed and rhizomes can be transported considerable distances by wildfowl or by water currents and wind (when dry). Floating fragments of *Ruppia* spp. grow roots freely, sink and attach to the bottom. Orth & Moore (1982; cited in Kantrup, 1991) reported that sediments denuded by a boat propeller was recolonized at about 0.25m/ year. Therefore, once rhizomes or seed arrive in the habitat recovery may take several years, however, recovery will depend on the time taken for *Ruppia* propagules to reach the available habitat. In areas connected by water flow or regularly frequented by wildfowl recovery will take many years, but in isolated, habitat recovery may be prolonged, suggesting a resilience of 'Medium' (2-10 years).

Benthic infauna is probably more stable, remaining when the *Ruppia* spp. die back. However, recolonization is thought to be rapid in *Arenicola marina* where adjacent population exist. In Broström & Bonsdorff (2000) experiments the polychaete *Pygospio elegans* and juvenile *Macoma baltica* had begun to colonize the habitat with 21 days and large numbers of both species were present by day 57. The community is, therefore, likely to recover rapidly, suggesting a 'high' resilience. However, in isolated lagoons and sea lochs recovery may take longer depending the proximity of similar communities from which recruitment can occur.

Several factors may inhibit or prevent recovery; loss of preferred habitat, competition and bioturbation or feeding by benthic infauna. Verhoeven (1979) noted that *Ruppia* spp. have little ability to compete with other, more vigorous aquatic plants and, therefore, most frequently occur in environments of variable salinity and temperature that other species can not endure (Verhoeven, 1979; Kantrup, 1991). Similarly, competition with infauna such as *Hediste diversicolor* or *Arenicola marina* have been suggested to hamper potential recruitment in *Zostera noltei* (see review) (Hughes *et al.*, 2000; Philippart, 1994a) and *Corophium volutator* has been reported to inhibit colonization of mud by *Salicornia* sp. (Hughes *et al.*, 2000). Therefore when abundant, the above infaunal species could potentially inhibit recruitment and hence recovery in *Ruppia* spp.

Resilience assessment. The *Ruppia* beds annually die back and regrow from seed or rhizome, suggesting that resilience is likely to be 'High' as long as the seed bank and rhizomes remain intact. Pressures that remove the seed bank or rhizomes, or change the habitat, will result in longer recovery periods, especially in isolated areas, suggesting resilience of Medium (2-10 years).

It should be noted that the recovery rates are only indicative of the recovery potential. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: High A: High C: High	High Q: High A: Low C: Medium	Not sensitive Q: High A: Low C: Medium

Temperature is considered the overall parameter controlling the geographical distribution of angiosperms. All enzymatic processes related to plant metabolism are temperature dependent and specific life cycle events, such as flowering and germination, are also often related to temperature (Phillips *et al.*, 1983). For marine plants, temperature affects biological processes by increasing reaction rates of biological pathways. Photosynthesis and respiration increase with higher temperature until a point where enzymes associated with these processes are inhibited. Beyond a certain threshold, high temperatures will result in respiration being greater than photosynthesis resulting in a negative energy balance. Increased temperatures do also encourage the growth of epiphytes increasing the burden upon seagrass beds and making them more susceptible to disease (Rasmussen, 1977). Verhoeven (1979) noted that *Ruppia maritima* plants survived between 0 and 38°C, grew exponentially between 10 and 30°C and withstood fluctuations of 15°C in laboratory experiments. However, temperatures above 30°C were harmful if sustained for prolonged periods of times, and *Ruppia maritima* was replaced by *Potamogeton* *pectinatus* in high temperature environments such as in the vicinity of thermal effluent (Kantrud, 1991).

Species living among *Ruppia* found in lagoons and shallow lochs are probably adapted to fluctuating temperatures, while mobile species are likely to move to deeper waters. Benthic infauna are likely to be protected from temperature extremes by their benthic habit, however, a proportion of the *Arenicola marina* population may be lost at temperatures above 20°C, and excluded from habitats suffering from more extreme fluctuations in temperature.

Sensitivity assessment. A 5°C change in temperature for one month period or a 2°C change in temperature for one year are unlikely to severely affect *Ruppia* plants. Resistance is therefore assessed as 'High' resulting in a 'High' resilience score (no impact to recover from). *Ruppia maritima* has a very wide temperature tolerance and is deemed ‘Not sensitive’ to this pressure.

Temperature decrease (local)	High Q: High A: High C: High	High Q: High A: Low C: Medium	Not sensitive Q: High A: Low C: Medium

A decrease in temperature is likely to delay the onset of budding and germination and subsequent reproduction in *Ruppia* spp., which may be of particular importance for annual species (see above). Verhoeven (1979) noted that all *Ruppia* taxa survive between 0-38°C, grow exponentially at 10-30°C and survive daily fluctuations of 15°C in culture. Kantrup (1991) reported that in North American wetlands that freeze in winter, *Ruppia* spp. behaved as annuals. Verhoeven (1979) reported that the distribution of *Ruppia maritima* and *Ruppia cirrhosa* extended north to Norway (ca 69 deg N and 68 deg N respectively), suggesting that these species would be tolerant of the average winter temperatures encountered in the UK. Therefore, *Ruppia* spp. are probably not sensitive to temperature increase at the level of the benchmark.
Many of the species found within the *Ruppia* spp. communities are typically lagoonal or shallow water species, adapted to fluctuating temperatures. Infaunal polychaetes are protected from temperature extremes by their burrowing habit, however, a proportion of the Arenicola marina population may be lost below 5 °C on in areas subject to extreme fluctuations in temperature. Overall, the *Ruppia* spp. stand will not be damaged by a decrease in temperature at the benchmark level but some species will reduce in abundance while mobile species may move to deeper water resulting in a reduced species richness.

Sensitivity assessment. A 5°C change in temperature for one month period or a 2°C change in temperature for one year are unlikely to severely affect *Ruppia* plants. Resistance is therefore assessed as 'High' resulting in a 'High' resilience score (no impact to recover from). *Ruppia maritima* has a very wide temperature tolerance and is deemed ‘Not sensitive’ to this pressure.

Salinity increase (local)	High Q: Medium A: Medium C: Medium	High Q: High A: Low C: Medium	Not sensitive Q: Medium A: Low C: Medium

Ruppia maritima has a wide salinity tolerance and is found growing in full saline, brackish as well as freshwater environments. *Ruppia* spp. tolerate a wider range of ionic strengths and salinities than any other aquatic angiosperm, occurring between 0.6 -390g/l (Kantrup, 1991). However, the reported salinity tolerances vary with region and with species. *Ruppia maritima* was reported to be abundant at salinities between 15 ->100g/l in North American wetlands and between 0.57 -27g/l in European sites (Verhoeven, 1979; Kantrup, 1991). *Ruppia cirrhosa* tolerated 2.7-108.3 g/l in European sites (Verhoeven, 1979). Kantrup (1991) concluded that the optimum salinity for *Ruppia* spp. Growth was 5-20 g/l while slightly lower salinities early in spring may enhance germination and seed formation. Rapid fluctuations were found to kill *Ruppia* spp. when salinities rise >ca 18g/l in a few weeks (Verhoeven, 1979). However, *Ruppia* spp. was also reported to survive a drop of at least 14 g/l in 24 hrs (Kantrup, 1991). Overall, *Ruppia* spp. are probably not directly sensitive changes in salinity at the benchmark level. Their exclusion from very low to freshwater, or nearly full seawater is probably due to competitive exclusion by other aquatic plants or seagrasses.

As the salinity increases low salinity species are likely to be replaced by comparable marine forms. Typically lagoonal species (e.g. the hydrobids, some gammarids, and *Cerastoderma glaucum*) are adapted to a wide range of salinities and are unlikely to be affected. Estuarine and low salinity polychaetes present in the benthos are likely to be replaced by more marine species as the salinity increases, e.g. the abundance of *Hediste diversicolor* is likely to fall while the abundance of *Arenicola marina* may increase. Sticklebacks are found in marine and freshwater habitats and the sand goby tolerates a wide range of salinities. Therefore, the biotope as a whole will probably be little affected by increases in salinity at the benchmark level, although some species may be replaced by more marine members of the same group.

Sensitivity assessment. *Ruppia maritima* exclusion from freshwater or nearly full seawater habitats is most probably due to competitive exclusion by other aquatic plants. An increase in salinity from 35 to >40 units for one year is unlikely to severely affect *Ruppia* plants. Resistance is therefore assessed as 'High' resulting in a 'High' resilience score (no impact to recover from). Overall *Ruppia maritima* has a very wide salinity tolerance and is assessed as ‘Not sensitive’ to an increase in salinity.

Salinity decrease (local)	Medium Q: Medium A: Medium C: Medium	High Q: High A: Low C: Medium	Low Q: Medium A: Low C: Medium

Ruppia maritima is found growing in full saline, brackish as well as freshwater environments and has, therefore, a wide salinity tolerance (Kantrud, 1991). However, La Peyre & Rowe (2003) found that relative growth rate of *Ruppia maritima* was significantly lowered during a short experimental freshwater pulse but without reporting any mortalities. *Ruppia* spp. are probably not directly intolerant of changes in salinity at the benchmark level (see above). Their exclusion from very low salinity to freshwater is probably due to competitive exclusion by other aquatic plants, e.g. *Potamogeton pectinatus*.

Most of the typically lagoonal species (e.g. *Cerastoderma glaucum*, *Gammarus insensibilis* and hydrobids) will be little affected by changes in salinity. However, *Gammarus insensibilis* was reported to disappear in areas affected prolonged exposure to freshwater. Similarly, *Arenicola marina* does not tolerate salinities below 24 psu and is likely to be replaced by *Hediste diversicolor*. Sticklebacks are found in marine and freshwater habitats and the sand goby tolerates a wide range of salinities. As the salinity decreases the species composition is likely to change towards more freshwater tolerant species, including insects, although the functional groups will probably remain, and the species richness may increase.

A short-term decrease in salinity is unlikely to affect the biotope adversely. However, prolonged exposure to low salinities or freshwater is likely to result in the replacement of the *Ruppia* community by other aquatic plant communities e.g. *Potamogeton pectinatus*. Once prior conditions return recovery is likely to be rapid.

Sensitivity assessment. *Ruppia maritima* exclusion from freshwater or nearly full seawater habitats is most probably due to competitive exclusion by other aquatic plants. A decrease in salinity from 'reduced' to 'low' salinity for one year is unlikely to severely affect *Ruppia* plants due to competition. Resistance is therefore assessed as 'Medium' to represent the potential loss of extent or abundance, but once the salinity returns to prior levels, recovery is likely to be rapid and resilience is probably 'High'. Overall *Ruppia maritima* beds are assessed as ‘Low’ sensitivity to a decrease in salinity at the benchmark level.

Water flow (tidal current) changes (local)	Low Q: High A: High C: High	Medium Q: High A: Low C: Medium	Medium Q: High A: Low C: Medium

The SS.SMp.SSGr.Rup biotope is found in extremely sheltered conditions in very weak tidal streams. An increase in water flow at the benchmark level is likely to damage leaves and shoots and probably remove the vegetation and a proportion of the root system. The root system of *Ruppia* spp. is poorly developed consisting of horizontal runners a few millimetres below the sediment surface and only 1-2 thin roots per 10-20 cm along the rhizome. Therefore, *Ruppia* spp. are not very resistant of water flow and are limited to still, sheltered waters such as lagoons and bays where current flow is less than in adjacent channels and tidal rivers (Verhoeven, 1979; Kantrup, 1991). Verhoeven (1979) suggested that *Ruppia maritima* was particularly intolerant while *Ruppia cirrhosa* occurred in larger waters at more exposed but still sheltered sites. In addition, turbulent water flow resulting in resuspension of sediment can indirectly reduce Ruppia productivity due to increased turbidity (see below). Kantrup (1991) reported that *Ruppia* spp. can occur in areas of 'considerable' current flow, e.g. *Ruppia* beds fertilized in situ with phosphorus were found to grow well in currents up to 4cm/s. However, 4cm/s is considered to be negligible (see benchmark). Epiphytes and algal mats would also be lost.

Most of the benthic infauna are found in areas of stronger currents (e.g. *Arenicola marina*), and many of the mobile species (e.g. amphipods, isopods, shrimp, crabs and fish) would migrate to other suitable substrata or habitats. However, where present *Cerastoderma glaucum* is only found in areas of weak water flow and may be lost.

Sensitivity assessment. Any change in water movement will have a considerable impact on the integrity of seagrass habitat. A change in water flow at the level of the benchmark of 10 to 20 cm/s for more than 1 year would remove of the *Ruppia maritima* plants by removal of the muddy substratum and drag on the plants. Resistance is thus assessed as ‘Low’. Once the water flow regime returned to prior conditions then recovery would probably take 2-10 years, a ‘Medium’ resilience. Overall, *Ruppia maritima* has a ‘Medium’ sensitivity to this pressure.

Emergence regime changes	Medium Q: High A: High C: High	Medium Q: High A: Low C: Medium	Medium Q: High A: Low C: Medium

Ruppia maritima occurs in tidal areas, from mean high water (MHW) to mean low water (MLW). Kantrud (1991) reported that the grass is restricted to areas exposed for a maximum of four hours daily or approximately seven hours per low tide but quickly disappeared from areas emersed for extended periods. Verhoeven (1979) stated that the *Ruppia* spp. had a low tolerance to drought as plants (except ripe seeds) died within a few days of being exposed to aerial conditions. Changes in emergence regime and increased aerial exposure are thus likely to result in reduced growth, productivity and the loss of the upper portion of the population.

Other components of the community might also be affected. For instance *Cerastoderma glaucum* is thought to be intolerant of changes in emergence and may be lost. *Hydrobia* spp. on the other hand inhabit salt marshes and are tolerant of emersion. Gammarids and isopods can either migrate to deeper water, burrow in the sediment of find shelter in damp weed to avoid aerial exposure. Algal mats retain water, and while their surface may be bleached or desiccate in hot weather, they are likely to recover quickly.

Sensitivity assessment. Seagrass growing in intertidal habitats have greater tolerance to exposure to air than species inhabiting subtidal beds. Changes in emergence regime will however cause some mortality in *Ruppia* plants resulting in a reduction in the upper shore extent. Resistance is therefore assessed as ‘Medium’. Recovery will be enabled by recolonization from surrounding communities located further down the shore and via the remaining seed bank. Recovery is therefore considered to be fairly rapid resulting in a ‘Medium’ resilience score. The biotope has a ‘Medium’ sensitivity to this pressure.

Wave exposure changes (local)	Medium Q: Medium A: Medium C: Medium	Medium Q: High A: Low C: Medium	Medium Q: Medium A: Low C: Medium

McCann (1945) noted that waves caused injury to *Ruppia* branches leaving broken tips incapable of survival, and Verhoeven (1979) observed that the base of leaves detached easily in turbulent water to avoid damage to the root system. However, the root system is weak (see water flow) and *Ruppia* beds are restricted to areas protected from wave action and with little fetch and wind induced water turbulence. Wave action also resuspends sediment, increasing turbidity and hence reducing productivity. This biotope (SS.SMp.SSgr.Rup) is found in extremely sheltered areas, therefore, and increase in wave action is likely to remove the surface vegetation and the majority of the root system.

Most lagoonal species are adapted to sheltered conditions and are likely to be adversely effected by increases in wave exposure, e.g. *Gammarus insensibilis* and *Cerastoderma edule* resulting in loss of a proportion of the population. The resident gastropods e.g. *Hydrobia ulvae* are unlikely to be directly affected, and will switch to alternative food supplies, however, should the increase in wave exposure be significant enough to change the sediment type, e.g. to coarse sands, they are likely to be lost. Benthic species, such as *Arenicola marina* can tolerate sheltered to moderately exposed conditions and would probably be little affected at the benchmark level.

Wave action also continuously mobilises sediments in coastal areas causing sediment re-suspension which in turn leads to a reduction in water transparency (Koch, 2001) (see 'changes in suspended sediments’ pressure). Photosynthesis can be further limited by breaking waves inhibiting light penetration to the seafloor. Wave exposure can also influence the sediment grain size, with areas of high wave exposure having coarser sediments with lower nutrient concentrations. Coarser sediments reduce the vegetative spreading of seagrasses and inhibit seedling colonization (Gray & Elliott, 2009). Changes in sediment type can therefore have wider implications for the sensitivity of the beds on a long-term scale.

Sensitivity assessment. Exposure models from Studland Bay and Salcombe, where seagrass beds are limited to low wave exposure, show that even a change of 3% (in significant wave height) is likely to influence the upper shore limits as well as beds living at the limits of their wave exposure tolerance (Rhodes *et al.*, 2006; Jackson *et al.*, 2013). The root system of *Ruppia* is more fragile than that of seagrass and, therefore, more likely to be damaged. At the benchmark level, an increase in wave exposure is likely to remove surface vegetation and the majority of the root system causing mortality. Resistance is thus assessed as 'Low'. Recovery will depend on the presence of adjacent seagrass beds and is considered to be fairly rapid scoring a 'Medium' resilience. The biotope therefore scores a 'Medium' sensitivity to changes in wave exposure at the pressure benchmark.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Little information concerning the effects on non-synthetic compound contamination *Ruppia maritima* was found. Other seagrasses such as *Zostera marina* are known to accumulate TBT but no detrimental effects were observed in the field (Williams *et al.*, 1994). Naphthalene, Pentachlorophenol, Aldicarb and Kepone reduce nitrogen fixation and may affect *Z. marina* viability. TBT contamination is likely to adversely affect grazing gastropods resulting in increased algal growth, reduced primary productivity and potential smothering of the biotope. Bryan & Gibbs (1991) suggested that TBT may cause reproductive failure or larval mortality in bivalve molluscs, e.g. *Pecten maximus* at ca. 50 ng/l TBT.

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Little information was found on the effects of hydrocarbon contamination from on *Ruppia* plants. However healthy populations of *Zostera* sp. have been observed in the presence of long-term, low level, hydrocarbon effluent, for example in Milford Haven, Wales (Hiscock, 1987). The Amoco Cadiz oil spill off Roscoff caused *Zostera marina* leaves to blacken 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). The Amoco Cadiz oil spill did however result in virtual disappearance of Amphipods, Tanaidacea and Echinodermata from *Zostera marina* beds and caused a decrease in numbers of Gastropoda, sedentary Polychaeta and Bivalvia. The numbers of most groups returned to normal within a year except Echinoderms which recovered more slowly and Amphipods which did not show any signs of recovery (Jacobs, 1980). Removal of oil intolerant gastropod grazers may result in smothering of seagrasses by epiphytes (Davison & Hughes, 1998). Jacobs (1980) noted a larger algal bloom than in previous years after the Amoco Cadiz spill in Roscoff, probably as a result in increased nutrients (from dead organisms and breakdown of oil) and the reduction of algal grazers. However, herbivores recolonized and the situation returned to 'normal' within a few months.

Experimental treatment of *Zostera* sp. with crude oil and dispersants halted growth but had little effect on cover whereas pre-mixed oil and dispersant caused rapid death and significant decline in cover within 1 week suggesting that dispersant treatments should be avoided (Davison & Hughes, 1998).

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Johnston & Bird (1995) determined that *Ruppia maritima* was able to better tolerate the effects of herbicides compared to other aquatic plants. Although photosynthesis was reduced by 0.05 mg/l atrazine after 35 days exposure, growth was reduced at atrazine concentrations < 5mg/l but continued at 10 mg/l. However, Kantrup (1991) reported that herbicides (atrazine and alachlor) in agricultural runoff reduced *Ruppia* growth and biomass in Chesapeake Bay and noted that 1.0 ppm of atrazine had been used to control *Ruppia* growth in wetlands. Only small numbers of plants survived 4 years after treatment with the herbicide 2,4 D-ester at 112 kg/ha (Kantrup, 1991). Cole *et al.* (1999) suggested that herbicides were, not surprisingly, very toxic to algae and macrophytes. Similarly, most pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods, isopods, mysids, shrimp and crabs) as well as fish (Cole *et al.*, 1999). For example, Lindane was shown to be very toxic to gobies (Gobius spp.: see *Pomatoschistus minutus*) (Ebere & Akintonwa, 1992) .

Synthetic chemicals found in agricultural, urban and industrial discharges are likely to adversely affect the biotope. Herbicides in particular are likely to reduce growth and productivity of *Ruppia* beds, and may result in mortality. In addition, loss of particularly intolerant crustaceans may result in unchecked growth of epiphytes, which would again reduce photosynthesis and productivity of *Ruppia* plants.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation	High Q: Medium A: Medium C: Low	High Q: Low A: NR C: NR	Not sensitive Q: Low A: NR C: NR

The effects of oxygen concentration on the growth and survivability of *Ruppia maritima* are not reported in the literature. However, *Ruppia* spp. favour aerobic sediments with low levels of sulphides and free H_2S but will grow in reduced conditions, since the leaves supply oxygen to the roots. Senescence and loss of stems can coincide with increases in H_2S in the sediment and may be a factor regulating the decrease in *Ruppia* species in hot summer months (Kantrup, 1991). Germination may also be affected by oxygen levels and seeds in poorly oxygenated sediments lie dormant until the next year (Kantrup, 1991). However, the presence of *Ruppia* in reduced sediment suggests that it would tolerate low oxygen levels comparable to the benchmark, especially since photosynthesis produces oxygen.

Mud snails are relatively tolerant of reduced hypoxic muds, and can tolerate aerial exposure for over a week, suggesting that they are capable of anaerobic respiration. Benthic infaunal species are probably tolerant of hypoxia, e.g. *Arenicola marina* which can tolerate 9 days without oxygen (Hayward, 1994) and *Cerastoderma glaucum* which tolerates 84 hrs in the absence of oxygen (Boyden, 1972). Most polychaetes are capable of anaerobic metabolism, while mobile fish and gobies migrate out of the affected area in response to decreasing oxygen levels (Diaz & Rosenberg, 1995). Small mobile shrimp, amphipods and isopods will probably also migrate out of the affected area.

Sensitivity assessment. Therefore, the *Ruppia* stands and benthic infauna will probably tolerate hypoxia at the level of the benchmark but increased epiphyte growth due to reduced numbers but not loss of grazers, may reduce *Ruppia* spp. productivity. However, species richness is likely to decline. Therefore, a resistance of 'High' is recorded, with a resilience of 'High', and resultant sensitivity of 'Not sensitive' at the benchmark level.

Nutrient enrichment	High Q: NR A: NR C: NR	High Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

In mesocosm experiments, *Ruppia maritima* was shown to increase shoot production by >300% over controls after the addition of 10µM water column NO_3-N /day (Burkholder *et al.*, 1994). Burkholder *et al.* (1994) went on to suggest that *Ruppia maritima* and *Halodule wrightii* effectively control nitrate uptake and could be transplanted to replace *Zostera marina* in nitrate-enriched waters where the eelgrass had disappeared. Therefore, it appears that Ruppia spp. will benefit from low nutrient enrichment. Nutrient enrichment is known to have indirect adverse effects. Nutrient enrichment stimulate epiphyte growth, which interfere with the nutrient exchange across the *Ruppia* leaves and shade out light, reducing primary productivity, growth and reproduction. Similarly, nutrients stimulate phytoplankton blooms that compete for nutrients but more importantly increase the turbidity (see water clarity). and absorb light, reducing *Ruppia* productivity. Twilley *et al.* (1985) found that epiphyte growth in nutrient enriched conditions reduced the light incident on *Ruppia* leaves by >80%, resulting in significant decreases in macrophyte biomass at medium to high levels of enrichment (0.86 and 1.68 g N /m□/ day respectively). *Ruppia maritima* production collapsed after 6 weeks at high nitrogen levels. However, the epiphytic growth only resulted in loss of macrophytes due to the additional turbidity caused by the phytoplankton (Twilley et al., 1985). Kantrup (1991) concluded that while nutrients can stimulate growth, growth is severely limited by phytoplankton and epiphytes in eutrophic conditions.

Ruppia spp. can tolerate organic rich sediments and has been reported to grow in extremely reduced sediments since leaves supply oxygen to the root system (Kantrup). However, Azzoni *et al.* (2001) noted that the oxygen supply to the roots detoxified the sulphide levels around the root system but that once this capacity was exhausted, perhaps due to additional nutrients or reduction in plant productivity, sulphide rapidly built up and killed the root system and hence the plant.

The nationally scarce foxtail stonewort *Lamprothamnium papulosum* was reported to be absent where the total phosphate concentration was greater than 100µg/l and may be lost due to nutrient enrichment (Bamber *et al.*, 2001). Most grazing and suspension and deposit feeding members of the community will probably benefit from the increased epiphyte and phytoplankton productivity, as would their predators.

Sensitivity assessment. The productivity and growth of the *Ruppia* beds are likely to be reduced by nutrient enrichment, and a proportion of the population lost, while significant increase in nutrients and subsequent eutrophication may result in loss of the biotope. However, at the benchmark of this pressure (compliance with WFD 'good' status) the biotope is 'Not sensitive' (Resistance and resilience are 'High').

Organic enrichment	No evidence (NEv) Q: Medium A: Medium C: Medium	No evidence (NEv) Q: High A: Low C: Medium	No evidence (NEv) Q: Medium A: Low C: Medium

Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see 'nutrient enrichment' pressure). Evidence on the effects of organic enrichment on *Ruppia* is limited, but abundant for other seagrass species. Neverauskas (1987) investigated the effects of discharged digested sludge from a sewage treatment on *Posidonia* spp. and *Amphibolis* spp. in South Australia. Within 5 years the outfall had affected an area of approximately 1900 ha, 365 ha of which were completely denuded of seagrasses. The author suggests that the excessive growth of epiphytes on the leaves of seagrasses was a likely cause for reduced abundance. A subsequent study by Bryars and Neverauskas (2004) determined that 8 years after the cessation of sewage output, total seagrass cover was approximately 28% of its former extent. While these results suggest that seagrasses can return to a severely polluted site if the pollution source is removed, they also suggest that it will take many decades for the seagrass community to recover to its former state. The effects of organic enrichment from fish farms were investigated on *Posidonia oceanica* seagrass beds in the Balearic Islands (Delgado *et al*., 1999). The fish culture had ceased in 1991; however, seagrass populations were still in decline at the time of sampling. The site closest to the former fish cages showed a marked reduction in shoot density, shoot size, underground biomass, sucrose concentration and photosynthetic capacities. The shoot also had high P-concentration in tissues and higher epiphyte biomass compared to the other sites. Since water conditions had recovered completely by the time of sampling, the authors suggest that the continuous seagrass decline was due to the excess organic matter remaining in the sediment (Delgado *et al*., 1999). It should be noted that coastal marine sediments where seagrasses grow are often anoxic and highly reduced due to the high levels of organic matter and slow diffusion of oxygen from the water column to the sediment. Seagrasses are adapted to these conditions but if the water column is organically enriched, plants are unable to maintain oxygen supply to the meristem and die fairly quickly. The enrichment of the water column could therefore significantly increase the sensitivity of seagrasses to this pressure.

Sensitivity assessment. No evidence on the effects of organic enrichment on *Ruppia* beds was found. The effects might be similar to those associated with nutrient enrichment but no assessment has been made.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure. *Ruppia maritima* will be unable to recover from a permanent loss of habitat resulting in a 'Very Low' resilience score. Sensitivity within the direct spatial footprint of this pressure is therefore ‘High’. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure. Adjacent habitats and species populations may be indirectly affected where meta-population dynamics and trophic networks are disrupted and where the flow of resources e.g. sediments, prey items, loss of nursery habitat etc. is altered

Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

Ruppia maritima occurs almost exclusively in shallow and sheltered coastal waters anchored in sandy and muddy bottoms. A physical change to another seabed type, i.e. from sedimentary to hard rock substratum would result in loss of the *Ruppia* bed and its associated community. As a permanent change, there is no opportunity for recovery without intervention. Therefore, the resistance is 'None', and resilience is 'Very Low', resulting in a sensitivity of 'High'. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

This biotope is only recorded from muds and muddy sands. Therfore, a change from muddy sand to mud or will probably have no effect. However, a change to coarser sediments, e.g. coarse sands, or mixed will probably adversely affect the biotope, resulting in exclusion of *Ruppia*. Therefore, a change to another seabed type will however result in a permanent loss of suitable habitat for this biotope. Resistance is thus assessed as ‘None’. As this pressure represents a permanent change, recovery is unlikely without intervention and resilience is assessed as ‘Very low’. The habitat therefore scores a ‘High’ sensitivity. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Habitat structure changes - removal of substratum (extraction)	None Q: High A: High C: High	Very Low Q: High A: Low C: Medium	High Q: High A: Low C: Medium

The extraction of sediments to 30 cm (the benchmark) will result in the removal of every component of *Ruppia* beds. Roots and rhizomes are buried no deeper than 20 cm below the surface (see ‘abrasion’ pressures). Resistance is therefore assessed as ‘None’ for all seagrass biotopes and resilience is considered ‘Very Low’ resulting in a ‘High’ sensitivity score.

Abrasion/disturbance of the surface of the substratum or seabed	Low Q: High A: Medium C: Medium	High Q: High A: Low C: Medium	Low Q: High A: Low C: Medium

d'Avack *et al.* (2014) reviewed the impacts of physical damage (abrasion and penetration) seagrasses to the pressure benchmark. The report found that a large amount of research had been conducted with however the majority of studies focusing on *Zostera* species. The sensitivity of *Ruppia* to this pressure is thus largely based on expert judgement but with a high level of confidence due to the morphology of the plant. Similar to *Zostera* species, *Ruppia maritima* has a shallow and weak root system and is incapable of vertical rhizome growth. Seagrasses are not physically robust. *Ruppia* stems and leaves are damaged by wave action or water turbulence and the root system is shallow and weak (Verhoeven, 1979; Kantrup, 1991). Therefore, it is likely that *Ruppia* spp. are intolerant of physical disturbance and that a proportion of the vegetation may be removed and rhizomes broken by any physical disturbance, e.g. trampling, anchoring, power boating and potting. However, in subtropical areas wintering wildfowl were reported to consume entire stands of *Ruppia* spp. which grew back in a few weeks (Kantrup, 1991). Similarly, Steiglitz (1966, cited in Kantrup, 1991) suggested that wildfowl could consume 50% of the standing crop without damaging the *Ruppia* bed.

Benthic infauna such as polychaetes (e.g. *Arenicola marina* or *Pygospio elegans*) are partly protected from abrasion due to their infaunal habit but a proportion are likely to be killed by any mechanical disturbance that penetrates the sediment (e.g. anchors). Similarly, the shell of *Cerastoderma glaucum* is relatively thin and individuals are likely to be damaged or killed by abrasion. Macroalgae and relatively flexible and unlikely to be damaged. However, resident grazers (e.g. gammarid amphipods, isopods, or gastropods) are likely to be killed by direct physical contact, although they are generally small enough to be swept aside, or able swimmers and most will probably escape.

Sensitivity assessment. *Ruppia* beds are particularly fragile and likely to be damaged by physical disturbance, so that a resistance of 'Low' is suggested. However, rhizomes and the seed bank remain, recovery will be rapid, so that their resilience is probably 'High', resulting in a sensitivity of 'Low' .

Penetration or disturbance of the substratum subsurface	Low Q: High A: Low C: Medium	High Q: Medium A: Low C: Medium	Low Q: Medium A: Low C: Medium

d'Avack *et al*. (2014) reviewed the impacts of physical damage (abrasion and penetration) seagrasses to the pressure benchmark. The report found that a large amount of research had been conducted with however the majority of studies focusing on *Zostera* species. The sensitivity of *Ruppia* to this pressure is thus largely based on expert judgement but with a high level of confidence due to the morphology of the plant. Similar to *Zostera* species, *Ruppia maritima* has a shallow and weak root system and is incapable of vertical rhizome growth. Seagrasses are not physically robust. *Ruppia* stems and leaves are damaged by wave action or water turbulence and the root system is shallow and weak (Verhoeven, 1979; Kantrup, 1991). Therefore, it is likely that *Ruppia* spp. are intolerant of physical disturbance and that a proportion of the vegetation may be removed and rhizomes broken by any physical disturbance. However, in subtropical areas wintering wildfowl were reported to consume entire stands of *Ruppia* spp. which grew back in a few weeks (Kantrup, 1991). Similarly, Steiglitz (1966, cited in Kantrup, 1991) suggested that wildfowl could consume 50% of the standing crop without damaging the *Ruppia* bed.

Benthic infauna such as polychaetes (e.g. *Arenicola marina* or *Pygospio elegans*) are partly protected from abrasion due to their infaunal habit but a proportion are likely to be killed by any mechanical disturbance that penetrates the sediment (e.g. anchors). Similarly, the shell of *Cerastoderma glaucum* is relatively thin and individuals are likely to be damaged or killed by abrasion. Macroalgae and relatively flexible and unlikely to be damaged. However, resident grazers (e.g. gammarid amphipods, isopods, or gastropods) are likely to be killed by direct physical contact, although they are generally small enough to be swept aside, or able swimmers and most will probably escape.

Sensitivity assessment. *Ruppia* beds are particularly fragile and likely to be damaged by physical disturbance. Penetrative activities (e.g. demersal trawls and dredges) are likely to damage the rhizomes directly (as they lie within the top 5 cm of sediment) so that a resistance of 'Low' is suggested. However, where rhizomes and the seed bank remain, recovery will be rapid, so that their resilience is probably 'High', resulting in a sensitivity of 'Low'.

Changes in suspended solids (water clarity)	Low Q: High A: High C: High	Low Q: High A: Low C: Medium	High Q: High A: Low C: Medium

Water clarity is a vital component for seagrass beds as it determines the depth-penetration of photosynthetically active radiation of sunlight. Increased turbidity results from increases in dissolved organics (e.g. humic acids or gelbstoff), organic particulates and suspended sediment, or blooms of phytoplankton and zooplankton. Seagrasses have light requirements an order of magnitude higher than other marine macrophytes making water clarity a primary factor in determining the maximum depth at which plants can occur. *Ruppia* spp. require high light levels and only normally develop well in clear water and are always reduced or absent from turbid waters (Verhoeven, 1979). Joanen & Glasgow (1965) found that plants preferred turbidity levels less than 25-55 ppm (equivalent to 25-55 mg/l). Wetzel & Penhale (1983) compared the photosynthetic parameters of *Ruppia maritima* and *Zostera marina*. *Ruppia maritima* was found to be photosynthetically less efficient in low levels of underwater light compared to *Zostera marina*. *Ruppia maritima* has also relatively high ratio of chlorophyll ▯ to chlorophyll ▯ suggesting that it is less adapted to low-light environments than other seagrasses (Evans *et al*., 1986). A shading experiment by Congdon & McComb (1979) on *Ruppia maritima* determined that a 40% reduction in light availability resulted in a 50% reduction in standing crop.

Sensitivity assessment. Turbidity is an important factor controlling production and ultimately survival and recruitment of *Ruppia* plants. Populations are likely to survive short-term increases in turbidity however a prolonged increase in light attenuation e.g. a change from clear (<10 mg/l) to intermediate (10-100 mg/l) water clarity at the benchmark level for a year, especially at the lower depths of distribution, will probably result in loss or damage of the population. Resistance is therefore assessed as ‘Low’. A loss of *Ruppia* beds will promote the re-suspension of sediments, making recovery unlikely as seagrass beds are required to initially stabilise the sediment and reduce turbidity levels (Van der Heide *et al*., 2007). A high turbidity state appears to be a highly resilient alternative stable state in seagrass habitats; hence return to the seagrass biotope may be prolonged resulting in ‘Low’ resilience, yielding a ‘High’ sensitivity score.

Smothering and siltation rate changes (light)	Medium Q: Medium A: Medium C: Medium	Medium Q: High A: Low C: Medium	Medium Q: Medium A: Low C: Medium

Early life stages of seagrass, smaller in size than adult plants, are most vulnerable to this pressure as even a small load of added sediment will lead to the complete burial. A deposit of 5 cm of fine material will shade and damage buried leaves and stems resulting in loss of a proportion of the vegetation above the sediment surface, including the algal mats and epiphytes. Kantrup (1991) suggested that, although most seeds occur in the top 5 cm of sediment, seeds buried more than 10 cm in sediment would probably not germinate, so that smothering by 5 cm of sediment may reduce germination. Similar results were found by Bonis & Lepart (1994). Smothering in early spring may have a marked effect of the growth of *Ruppia* spp. stands, especially annuals that are primarily dependant on seed. The timing of the siltation event also plays a role in particular for intertidal beds. At low tide, the seagrass bed is exposed with plants lying flat on the substratum. The addition of material would immediately smother the entire plant and have a greater impact on leaves and stem than if added on plants standing upright. The resistance of intertidal beds to this pressure may thus vary with time of day. Most members of the invertebrate fauna will probably be able to burrow through or avoid smothering. However some grazers may be lost. Cockles (*Cerastoderma* sp.) have limited ability to burrow and may also be adversely affected.

Sensitivity assessment. Above studies suggest that *Ruppia maritima* is intolerant of smothering. At the level of the benchmark (5 cm of fine material added to the seabed) some mortalities may occur resulting in a 'Medium' resistance score. In addition, *Ruppia* beds are restricted to low energy environments, suggesting that once the silt is deposited, it will remain in place for a long period of time so habitat conditions will not reduce exposure. Resilience is therefore assessed as 'Medium'. The biotope is considered to have a ‘Medium’ sensitivity to siltation at the pressure benchmark.

Smothering and siltation rate changes (heavy)	None Q: Low A: NR C: NR	Very Low Q: High A: Low C: Medium	High Q: Low A: Low C: Low

Ruppia maritima is intolerant of smothering by excessive siltation. In addition, *Ruppia* beds are restricted to low energy environments, suggesting that once the silt is deposited, it will remain in place for a long period of time so habitat conditions will not reduce exposure. Resistance is assessed as ‘None’ as all individuals exposed to siltation at the benchmark level are predicted to die and consequent resilience as ‘Low’ to ‘Very Low’. Sensitivity based on combined resistance and resilience is therefore assessed as ‘High’.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

Introduction of light or shading	Low Q: High A: High C: Medium	High Q: High A: Low C: Medium	Low Q: High A: Low C: Medium

Ruppia spp. require high light levels and only normally develop well in clear water and are always reduced or absent from turbid waters (Verhoeven, 1979). Joanen & Glasgow (1965) found that plants preferred turbidity levels less than 25-55 ppm (equivalent to 25-55 mg/l). Wetzel & Penhale (1983) compared the photosynthetic parameters of *Ruppia maritima* and *Zostera marina*. *Ruppia maritima* was found to be photosynthetically less efficient in low levels of underwater light compared to *Zostera marina*. *Ruppia maritima* has also relatively high ratio of chlorophyll ▯ to chlorophyll ▯ suggesting that it is less adapted to low-light environments than other seagrasses (Evans *et al*., 1986). A shading experiment by Congdon & McComb (1979) on *Ruppia maritima* determined that a 40% reduction in light availability resulted in a 50% reduction in standing crop. Kantrud (1991) noted that poor insolation due to fog, mountains and short days reduced *Ruppia* sp. productivity. While *Ruppia* beds can survive short-term changes in turbidity, Kantrud (1991) concluded that the control of turbidity levels was crucial for the managment of *Ruppia* beds.

Sensitivity assessment. It is likely that 'shading' of a *Ruppia* bed would result in reduced growth and productivity, potential competition with shade tolerant species and, if prolonged, loss of the bed in a 'shaded' area. Therefore, a resistance of 'Low' is given, with a resilience of 'High', resulting in a sensitivity of 'Low'. However, if the 'shading' was caused by a permanent structure, then the resilience would be 'Very low' and sensitivity 'High'.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant. This pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit the dispersal of seed. But seed dispersal is not considered under the pressure definition and benchmark.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant. The potential effects of vessel grounding are covered under abrasion above.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Translocation of seagrass seeds, rhizomes and seedlings is a common practice globally to counter the trend of decline of seagrass beds. *Zostera marina* is the seagrass species most commonly translocated. Williams and Davis (1996) found that levels of genetic diversity of restored eelgrass *Zostera marina* beds. The loss of genetic variation can lead to lower rates of seed germination and fewer reproductive shoots, suggesting that there might be long-term detrimental effects for population fitness. Williams (2001) affirms that genetic variation is essential in determining the potential of seagrass to rapidly adapt to a changing environment. Transplanted populations are therefore more sensitive to external stressors such as eutrophication and habitat fragmentation, with reduced community resilience, compared to natural populations (Hughes & Stachowicz, 2004).

Even though restoration efforts tend to focus on *Zostera marina*, transplantations of *Ruppia maritima* (Bird *et al*., 1994) have also been undertaken and large areas of wetland planted with *Ruppia* to feed wildfowl in the USA (Kantrud, 1991). Similar reductions in genetic diversity are possible.

Translocation also has the potential to transport pathogens to uninfected areas (see 'introduction of microbial pathogens' pressure). The sensitivity of the 'donor' population to harvesting to supply stock for translocation is assessed for the pressure 'removal of target species'. No evidence was found for the impacts of translocated beds on adjacent natural seagrass beds. However, it has been suggested that translocation of plants and propagules may lead to hybridisation with local wild populations. If this leads to loss of genetic variation there may be long-term effects on the potential to adapt to changing environments and other stressors.

Sensitivity assessment: Presently, there is no evidence of loss of habitat due to genetic modification and translocation of *Ruppia* species.

Introduction or spread of invasive non-indigenous species	Low Q: Medium A: Medium C: Medium	Low Q: High A: Low C: Medium	High Q: Medium A: Low C: Medium

The effects on native species on seagrass species was reviewed by d'Avack *et al.* (2014). The review reported several non-native invasive plants as well as invertebrate species negatively impacting British seagrass beds. These included *Sargassum muticum*, *Spartina anglica*, *Codium fragile* ssp. *Tomentosoides*, *Didemnum vexillum*, *Urosalpinx cinerea* and *Magallana gigas.*

Sensitivity assessment. d'Avack *et al.* (2014) found that invasive flora had the greatest impact on seagrass bed but pointed out extensive knowledge gaps on how invasive species influence the health of *Zostera* beds in UK waters. More research is thus needed in order to fully comprehend this pressure. Resistance is assessed as 'Low'. Return to 'normal' conditions is highly unlikely if an invasive species would come to dominate the biotope. Indeed recovery would only be possible if the majority of the NIS were removed (through either natural or unnatural process) to allow the re-establishment of other species. Therefore actual resilience is assessed as 'Low' resulting in an overall 'High' sensitivity score.

Introduction of microbial pathogens	High Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Not sensitive Q: Low A: NR C: NR

Kantrup (1991) reported possible pathogenic effects of fungi, that produce 'tubercles' on the Ruppia leaves. Kantrup (1991) also states that 'vegetative reproduction usually allows *Ruppia* spp. to survive *Rhizoctonia* infestations' and that *Ruppia* spp. probably suffer less from diseases than other aquatic angiosperms.

Sensitivity assessment. Therefore, the above evidence suggests a resistance of 'High', a resilience of 'High' and, hence, a sensitivity of 'Not sensitive'.

Removal of target species	Low Q: Medium A: Medium C: Medium	High Q: High A: Low C: Medium	Low Q: Medium A: Low C: Medium

In accessible areas, extraction of *Arenicola* marina for bait is likely to disturb the sediment and benthic infauna, although the *Ruppia* stands themselves would probably recover quickly. Similarly, *Arenicola marina* populations are thought to recover rapidly, although in isolated areas recovery may take longer due to the lack of a pelagic larvae.

Removal of non-target species	None Q: Low A: NR C: NR	High Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

In accessible areas, extraction of *Arenicola* marina for bait is likely to disturb the sediment and benthic infauna, although the *Ruppia maritima* stands themselves would probably recover quickly. Similarly, *Arenicola marina* populations are thought to recover rapidly, although in isolated areas recovery may take longer due to the lack of pelagic larvae. Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of non-target species on this biotope.

Incidental removal of the key characterizing seagrass species and associated species would alter the character of the biotope. The biotope is characterized by the presence of beds of *Ruppia maritima*, these provide habitat structure and may also modify local habitats through changes in water flow and the trapping of sediments. The loss of the turf due to incidental removal as by-catch would, therefore, alter the character of the habitat and result in the loss of habitat structure and species richness. The ecological services such as primary and secondary production and habitat engineering provided by *Ruppia maritima* and the associated species would also be lost.

Sensitivity assessment. Incidental removal of *Ruppia* spp. as by-catch would be detrimental, altering the character of the biotope and removing the habitat structure, and could lead to reclassification of the biotope where extensive removal occurs. Therefore, resistance is considered to be 'None', resilience 'High' (but see caveats in the resilience section) and sensitivity 'Medium'.

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