Osmundea pinnatifida on moderately exposed mid eulittoral rock

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Marine Evidence–based Sensitivity Assessment (MarESA) Review

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***Osmundea pinnatifida* on moderately exposed mid eulittoral rock**
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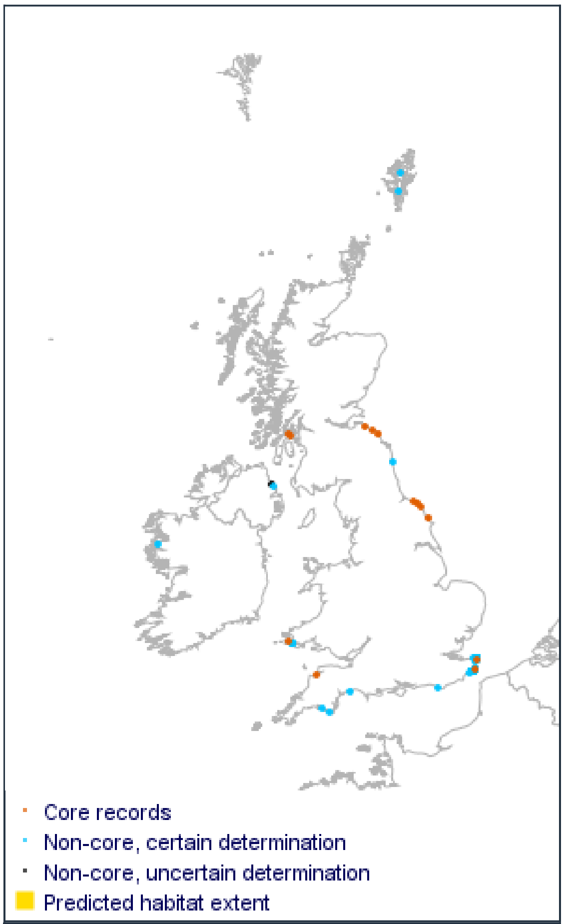

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.126	*Osmundea pinnatifida* on moderately exposed mid eulittoral rock
JNCC 2015	LR.HLR.FR.Osm	*Osmundea pinnatifida* on moderately exposed mid eulittoral rock
JNCC 2004	LR.HLR.FR.Osm	*Osmundea pinnatifida* on moderately exposed mid eulittoral rock
1997 Biotope	LR.MLR.R.Osm	Osmundea (Laurencia) pinnatifida and Gelidium pusillum on moderately exposed mid eulittoral rock

Description

Exposed to moderately exposed lower eulittoral rock may be characterized by extensive areas or a distinct band of *Osmundea* (*Laurencia*) *pinnatifida* and *Gelidium pusillum* (either together or separately). This community usually occurs on shores on which a fucoid canopy is reduced in extent, or even absent. Other turf-forming red algae, such as *Ceramium* spp. and *Callithamnion hookeri* may be present, although *Osmundea* and/or *Gelidium* always dominate. On flatter, more sheltered shores, *Laurencia hybrida* may also occur. Small patches of bare rock amongst the algal turf are occupied by barnacles *Semibalanus balanoides*, the limpet *Patella vulgata*, dog whelks *Nucella lapillus* and small mussels *Mytilus edulis*. A variation of this biotope has been described for the chalk platforms in Kent where extensive turfs of *Gelidium pusillum* occur in the mid eulittoral above the main *Osmundea* zone (Connor et al., 2004; JNCC).

Depth range

-

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and information on characterizing species are taken from Connor *et al.* (2004). This biotope occurs on lower eulittoral rock characterized by extensive areas or a distinct band of *Osmundea pinnatifida* and *Gelidium pusillum* (either together or separately). Other turf-forming red algae, such as *Corallina officinalis*, *Mastocarpus stellatus*, *Ceramium* spp. and *Callithamnion hookeri* may be present, although *Osmundea pinnatifida* always dominate. As *Osmundea pinnatifida* is the key characterizing species that defines the biotope the sensitivity assessments are focussed on this species, although the sensitivity of the other turf forming red algae are considered generally. Small patches of bare rock amongst the algal turf are occupied by barnacles *Semibalanus balanoides*, the limpet *Patella vulgata*, the whelk *Nucella lapillus* and small individuals of the mussel *Mytilus edulis*. The winkles *Littorina littorea* and *Littorina saxatilis* can be present on the rock or among the seaweeds. Unlike other biotopes grazing does not directly structure this biotope as *Osmundea pinnatifida* contains compounds that repel grazers and littorinids will not feed on the species, however grazing on other species may indirectly affect *Osmundea pinnatifida* and grazing may be important in consuming other species such as ephemeral algae that could otherwise dominate this biotope. The sensitivity of the associated grazers is therefore considered within the assessments as key structuring species. The species associated with the sediments within the turf occur in a number of biotopes and are not key characterizing species but do contribute overall to species richness, diversity and ecosystem function. The sensitivity of these species is considered generally and more information can be found in other biotope assessments.

Resilience and recovery rates of habitat

Where this biotope is impacted by pressures, recovery of the key structuring and characterizing species *Osmundea pinnatifida* will require either regrowth of fronds, regrowth from the surviving crustose holdfast or recolonization by propagules. Like other red algae *Osmundea pinnatifida* have complex life histories that alternate between sexual stages (male and female plants) and spore producing asexual stages (tetraspoprophytes). After fertilization the zygote develops into a spore producing carposporophyte attached to the female plant. The spores produced by the carposporophyte develop into a tetrasporophyte that produces male and female plants. In *Osmundea pinnatifida* tetrasporophytes and male and female plants are morphologically identical but may have different ecological tolerances and requirements. Alternation between life histories is not obligate and the proportion of sexual plants and asexual tetrasporophytes may vary. In habitats where conditions are unfavourable e.g. low salinity habitats, asexual reproduction may maintain populations by retaining genotypes that have evolved to tolerate the prevailing habitat conditions. Such effects have been observed for other red algal species but not described for *Osmundea pinnatifida*. Populations of *Osmundea pinnatifida* on the Isle of Man release tetraspores in April-May before die back of mature fronds in June (Prathep, 2001).

Turfs of *Osmundea pinnatifida* may expand through lateral growth of the perennial holdfast (Prathep, 2001). The crustose holdfast may have different tolerances to desiccation than fronds (Prathep, 2001) and may also exhibit greater resistance than the fronds to other pressures. Littler & Kauker (1984), suggested that the crustose bases of *Corallina officinalis* were adapted to resist grazing and desiccation whereas the fronds were adapted for higher primary productivity and reproduction. The basal crusts are tougher than the upright fronds (requiring a pressure of 94 g/mm^2 to penetrate compared to 43 g/mm^2). Where the holdfast remains and pre-empts colonization by other species it can provide an effective mechanism for recovery and is key to the survival of turfs on shore where bleaching and die-back of fronds occur in response to summer bleaching (Prathep, 2001). Regeneration from basal crusts can support more rapid recovery than recolonization. Experiments in the intertidal in southern California found that areas scraped back to *Corallina officinalis* crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1984). Turfs may also expand vegetatively where upright fronds bend over, produce rhizoids and colonize adjacent areas of bare rock by acting as stolons (Godin, 1981). Biomass of turfs varies seasonally: growth is greatest in the autumn and winter and fronds are bleached and die-back in summer on Isle of Man shores (Prathep, 2001). Prathep, (2001) noted that isolated individuals and small patches of *Osmundea pinnatifida* are uncommon on shores on the Isle of Man. Turfs are maintained by vegetative growth (Godin, 1981) rather than recolonization and the outer edges of patches undergo expansion and regression throughout the year (Prathep, 2001). Smaller patches demonstrated smaller expansion. Observed expansion rates are very small, 0.015 mm/month in limpet exclusion areas and 0.003 mm/month with limpets. In areas of bare rock on the Isle of Man monitored for a year on shores that were suitable for turfs no recruitment was observed (Prathep, 2001).

In the laboratory Prathep (2001) tested a number of stimuli to induce spore release, however, few spores were released and these took 2-3 days to settle and stick. Observed mortality rates were high (32-46 %) and growth was low (maximum height of tetrasporophytes of 2 cm after 3 weeks). Recruitment from spores is therefore unlikely to be effective in establishing new populations on bare rock. Limpet grazing may also play an important role in reducing expansion of existing turfs and preventing establishment of new turfs on open, bare rock, as small new patches were only observed in crevices and established turf on Isle of Man shores also appeared to have radiated from crevices or crustose algae protecting plants from desiccation and/or grazing (Prathep, 2001). In common with other red algae, the spores of *Osmundea pinnatifida* are non-flagellate, and non-motile. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition. However, due to the relatively large size of *Osmundea pinnatifida* tetraspores at 98 µm (Prathep, 2001, compared to red algal size range of 15-120 µm, Ngan & Price, 1979), the short growth and dense turf forming habit that reduces current speeds the spores may be retained within turfs and settle close to the adults.

Fragmentation of *Osmundea pinnatifida* turfs and decreases in density of fronds will increase desiccation and bleaching (Prathep, 2001) inhibiting recovery. Smaller patches of *Osmundea pinnatifida* damaged by winter wave action, repaired during the following year but did not fully recover their former extent (Prathep, 2001).

Grazers (limpets and littorinds) may structure the biotope through their presence or absence, where they are absent initial recolonization of the habitat by ephemeral green algae is likely.Turf forming biotopes and fucoid dominated biotopes may represent alternate stable states that are present while the dominant turf or fucoids occupy space. Removal of the turf may therefore allow re-establishment of a Fucoid or kelp dominated biotope that will remain until environmental or other factors again alter the state. Lubchenco (1980) for example, on shores in New England, found that the removal of *Chondrus crispus* turf allowed the establishment of *Fucus* spp. Removal of grazers and the turf allowed *Fucus* spp. to establish 100% cover, highlighting the significance of grazers in structuring the biotope. MacFarlane (1952) also recorded a shift to a *Corallina officinalis* and encrusting coralline biotope following over raking (for harvesting) of *Chondrus crispus* turf, in these areas gastropods had increased in abundance and prevented the recovery of *Chondrus crispus* by grazing. It should therefore be noted that where red algal turfs are removed, recovery may be prolonged and other species may replace *Osmundea pinnatifida* turfs. *Corallina officinalis* may rapidly recolonize areas that are cleared during the reproductive period. *Corallina officinalis* was shown to settle on artificial substances within 1 week of their placement in the intertidal in New England summer (Harlin & Lindbergh, 1977). In the lower rocky intertidal in southern California dominated by *Corallina officinalis* with foliose overstorey algae present, Littler & Kauker (1984) experimentally cleared plots and followed the recovery for 12 months. Some areas were scraped allowing the basal crusts to remain whereas others were completely sterilised (removal of all material and surfaces then scorched with a blow torch to remove bases). In scraped plots up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984) while in sterilized plots (all basal crusts removed) appearance of articulated fronds occurred 6 months following clearance. At the end of the 12 month observation period *Corallina officinalis* cover had increased to approximately 18% in plots where basal crusts remained and to approximately 10% in sterilised plots. Similarly Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed. Some repair of damaged encrusting coralline occurs through vegetative growth. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the Sea Empress spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Airoldi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months. As encrusting corallines are sensitive to desiccation (Dethier, 1994) it should be noted that these subtidal habitats are probably more favourable for recruitment, growth and survival than intertidal rock. Encrusting corallines appear to provide a suitable microhabitat for *Osmundea pinnatifida* settlement (Prathep, 2001), recovery of this biotope element may therefore support turf recovery.

Resilience assessment. Where resistance is ‘High’ resilience is assessed as ‘High’ as there is no effect to recover from. Where resistance is ‘Medium’ or ‘Low’ with removal of only fronds then recovery will occur via regrowth from the crustose holdfast and resilience is assessed as ‘High’ (within 2 years). Lateral expansion of adjacent turfs will allow recovery where the holdfasts are removed, however as growth is slow, resilience is assessed as ‘Medium’ (2-10 years). Successful recruitment may be sporadic, depend on exclusion of grazers and require favourable conditions such as reduced wave action, low insolation and the presence of crevices or crustose algae or turfs of other species (Prathep, 2001). Recovery where turf and holdfasts are removed (resistance is none) over an extended area may therefore be protracted and is assessed as ‘Medium-Low’ to reflect uncertainty. Caveats regarding possible state shifts where turfs are removed over a large extent of the habitat should also be considered when applying sensitivity assessments. The associated barnacles and grazing limpets and littorinids may recover rapidly (High resilience) where resistance is ‘Medium’ with mobile species migrating from adjacent populations, recovery may be ‘Medium’ (2-10 years) due to episodic recruitment success where resistance is ‘Low’ or ‘None’. The sediment dwelling infauna found within trapped sediments are largely small, short-lived species and recover rapidly from inward migration or recolonization (within days to months) where a turf (of any species) traps sediment.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. 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. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

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

Species found in the intertidal are exposed to extremes of high and low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in this intertidal biotope are therefore generally adapted to tolerate a range of temperatures, although the timing of site-specific factors such as low tides will influence local acclimation. For intertidal species increased temperatures may also result in desiccation when exposed (see changes in emergence pressure).

Fronds of *Osmundea pinnatifida* bleach and die-back in summer, the factors responsible for this are a combination of temperature (Flores-Maya, 1992, abstract only) desiccation and irradiance (Prathep, 2001). *Osmundea pinnatifida* is frequently found as an understorey species beneath fucoid canopies. In an exceptionally hot summer (1983, with an increase of between 4.8 and 8.5 °C) Hawkins & Hartnoll (1985) observed no temperature bleaching of canopy forming species. However, understorey red algae showed more signs of damage with bleached *Corallina officinalis* and 'lithothamnia' observed around the edges of pools due to desiccation. Occasional damaged specimens of *Palmaria palmata*, *Osmundea pinnatifida* and *Mastocarpus stellatus* were observed. This evidence suggests that this biotope would tolerate a chronic or acute increase in temperature at the pressure benchmark, particularly where canopy forming algae afforded some shade but that some bleaching of fronds of *Osmundea pinnatifida* would occur (although summer bleaching and die-back occurs on shores in the UK, Prathep, 2001).

The red algal species *Mastocarpus stellatus* and *Corallina officinalis* associated with this biotope may be found higher on the shore (Connor *et al*., 2004) and their distribution suggests that they have a higher tolerance to increased temperatures and desiccation than *Osmundea pinnatifida*. *Corallina officinalis* has a cosmopolitan distribution (Guiry & Guiry, 2015) and throughout its range experiences wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). Littler & Kauker (1984) suggested that the crustose bases of *Corallina officinalis* are more resistant of desiccation or heating than fronds. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived one week exposure to temperatures between 0 °C and 28 °C. Latham (2008) investigated the effects of temperature stress on *Corallina officinalis* through laboratory tests on samples collected in the Autumn in Devon, England from rockpools. Samples were kept at 15 °C for three days and then exposed to temperatures of 5 °C, 15 °C, 20 °C, 25 °C and 30 °C (the normal range of temperature experienced was suggested to be between 5 and 15 °C). At 35 °C the *Corallina was* completely bleached after 3 days with a sample kept at 30 °C beginning to bleach. After 7 days (the end of the experiment) the sample kept at 30 °C was partially bleached. Samples kept at 5, 15, 20 and 25 °C showed little change in chemicals produced in reaction to thermal stress and no bleaching suggesting the temperatures in that range had not induced stress reactions.

Coralline crusts, including *Lithophyllum incrustans* are found further south than the UK and are considered to tolerate increased temperatures (although they may be more sensitive to drying rather than higher temperatures). Edyvean & Ford (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b). *Lithophyllum incrustans* is close to the northern edge of its range and is likely to tolerate increased temperatures.

Most of the other species within the biotope are distributed to the north and south of Britain and Ireland and unlikely to be adversely affected by a chronic temperature change. Sandison (1968); (reported unpublished in Lewis, 1964) noted that heat coma occurred in *Nucella lapillus* at 27 -28 °C, and death at 32 -33 °C. Newell (1979) noted that oxygen consumption (hence metabolic rate) fell with decreased temperature and starvation, being low in winter but high in summer. This resulted in a high scope for activity, and dog whelks responded rapidly to increases in temperature in the spring. Newell (1979) pointed out that dog whelks could adjust their metabolic rate with temperature and season. Stickle *et al.* (1985) also noted that feeding and ingestion rates decreased with decreasing temperature and salinity. Increased temperatures increase the risk of desiccation, especially on sheltered shores. However, dog whelks demonstrate behavioural adaptations depending on the type of shore they inhabit, e.g. dog whelks from sheltered shores forage less in sunny, warm weather, whereas animals from wave exposed shores (higher humidity) favoured calm periods even when sunny (Burrows & Hughes, 1989; Fretter & Graham, 1994). Crothers (1985) suggested that the southern limit of dog whelk distribution was temperature dependant and noted that in Portugal dog whelks live inside mussels clumps and in Massachusetts, where water temperature may reach 25 °C, dog whelks may spend summer below the tide mark. Therefore, *Nucella lapillus* is probably relatively tolerant of temperature change within the normal range for the UK, and is probably tolerant to a change of 2 °C over a year. However, an acute temperature change (e.g. 5 °C) will probably interfere with feeding activity and in summer may result in direct mortality or indirect mortality due to heat coma and desiccation. Limpets, *Patella vulgata* and littorinids occur within this biotope. Laboratory studies suggest that adults of these species can tolerate temperature increases. The median upper lethal temperature limit in laboratory tests on *Littorina littorea*, *Littorina saxatilis* was approximately 35 ^{oC} (Davenport & Davenport, 2005). *Patella vulgata* can also tolerate high temperatures. The body temperature of *Patella vulgata* can exceed 36 °C in the field, (Davies, 1970); adults become non-responsive at 37-38 °C and die at temperatures of 42 °C (Evans, 1948).

Sensitivity assessment. The fronds of *Osmundea pinnatifida* undergo annual die-back in the summer while the crustose holdfasts remain suggesting that the bases are more resistant. *Osmundea pinnatifida* is considered to be able to tolerate a chronic and acute increase at the pressure benchmark although it is likely that acute increases in the summer will lead to die-back. Evidence suggests that the associated species *Corallina officinalis* and *Mastocarpus* *stellatus* that occur higher on the shore are likely to tolerate a wider range of temperatures. Biotope resistance is assessed as 'High' and resilience as 'High' by default, so that the biotope is considered to be 'Not sensitive'. Little direct evidence was available on the sensitivity of the key characterizing species *Osmundea pinnatifida* and confidence in this assessment is 'Low'. The associated species *Semibalanus balanoides* and *Patella vulgata* are close to the southern limit of their distribution. Adults are considered to be able to withstand an acute and chronic increase in temperature at the pressure benchmark. A chronic increase in temperature (for longer than the pressure benchmark) may also lead to recruitment failures of *Patella vulgata* and *Semibalanus balanoides* although this will not significantly alter the character of the biotope.

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

Many intertidal species are tolerant of freezing conditions as they are exposed to extremes of low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in the intertidal are therefore generally adapted to tolerate a range of temperatures, with the width of the thermal niche positively correlated with the height of the shore (Davenport & Davenport, 2005).

No evidence was found for tolerance of decreased temperatures by *Osmundea pinnatifida*.

The associated species *Mastocarpus stellatus* have a broad geographical distribution (Guiry & Guiry, 2015) and throughout the range experience wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). *Mastocarpus stellatus* is able to tolerate freezing conditions, the photosynthetic rate of *Mastocarpus stellatus* fully recovered from 24 hrs at -20 °C (Dudgeon *et al.* (1989). Other species associated with the biotope are able to tolerate decreases in temperature. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0 °C when exposed for one week. New Zealand specimens were found to tolerate -4 °C (Frazer *et al.*, 1988).

The limpet *Patella vulgata* and the barnacle *Semibalanus balanoides* are both northern species and relatively close to their southern range limit in the UK, suggesting these are tolerant of colder temperatures than those typically experienced in UK habitats. The tolerance of *Semibalanus balanoides*, collected in the winter (and thus acclimated to lower temperatures), to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -14.6 °C (Davenport & Davenport, 2005). The same series of experiments indicated that median lower lethal temperature tolerances for *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13 °C respectively. Adults of *Patella vulgata* are also largely unaffected by short periods of extreme cold. Ekaratne & Crisp (1984) found adult limpets continuing to grow over winter when temperatures fell to -6 °C. Loss of adhesion after exposure to -13 °C has been observed with limpets falling off rocks and therefore becoming easy prey to crabs or birds (Fretter & Graham, 1994). However, in the very cold winter of 1962-3 when temperatures repeatedly fell below 0 °C over a period of 2 months large numbers of *Patella vulgata* were found dead (Crisp, 1964). Periods of frost may also kill juvenile *Patella vulgata*, resulting in recruitment failures in some years (Bowman & Lewis, 1977).

In colder conditions an active migration by mobile species found within the turf may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less.

Sensitivity assessment. The fronds of *Osmundea pinnatifida* undergo annual die-back in the summer while the crustose holdfasts remain suggesting that the bases are more resistant. *Osmundea pinnatifida* is considered to be able to tolerate a chronic and acute increase at the pressure benchmark although it is likely that acute increases in the summer will lead to die-back. Evidence suggests that the associated species *Corallina officinalis* and *Mastocarpus stellatus* that occur higher on the shore are likely to tolerate a wider range of temperatures. Biotope resistance is assessed as 'High' and resilience as 'High' by default, so that the biotope is considered to be 'Not sensitive'. Little direct evidence was available on the sensitivity of the key characterizing species *Osmundea pinnatifida* and confidence in this assessment is 'Low'. The associated species *Semibalanus balanoides* and *Patella vulgata* are close to the southern limit of their distribution and evidence suggests that these species and littorinids can tolerate a decrease in temperature at the benchmark.

Salinity increase (local)	Low Q: Low A: NR C: NR	Low Q: Low A: NR C: NR	High Q: Low A: Low C: Low

No evidence was found to assess the salinity tolerances of *Osmundea pinnatifida*. As this biotope is present in full salinity (Connor *et al*., 2004), the assessed change at the pressure benchmark is a reduction in salinity to a variable regime (18-35 ppt) or reduced regime (18-30 ppt). Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity.

The associated species, *Corallina officinalis*, encrusting corallines and *Littorina littorea* are found in rockpools where salinities may fluctuate markedly during exposure to the air. Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons. Edyvean & Ford (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

Kirby *et al.* (1994b) simulated the effects of hyper-osmotic shock due to evaporation of mantle cavity retained seawater in *Nucella lapillus*. No mortalities were observed over the duration of the experiment where individuals were exposed to 35, 45, 55, 65 and 75 psu over periods of 6, 12 and 24 hrs at 15 °C. Overall, it appears that *Nucella lapillus* would tolerate an acute, short-term increase in salinity, albeit at metabolic cost.

Sensitivity assessment. Although some increases in salinity may be tolerated by the associated species present, the natural variation, (rather than the pressure benchmark) is generally short-term and mitigated during tidal inundation. This biotope is considered, based on distribution of *Osmundea pinnatifida* on the mid-shore, to be sensitive to a persistent increase in salinity to > 40 ppt. Resistance is therefore assessed as 'Low' and recovery as 'Medium-Low' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium-High' (the more precautionary assessment is presented in the table). The associated red algal turf species and invertebrates may have a greater tolerance than *Osmundea pinnatifida* and may recover more rapidly but some changes in abundance and composition are likely to occur where changes are long-term.

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

This biotope is recorded in full salinity habitats (Connor et al., 2004). However, high rainfall will reduce salinity on rocksurfaces when exposed to air and may create a surface layer of brackish/nearly freshwater for a period. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity. Local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances from populations in different regions. This biotope is found in full (30-35 ppt) salinity (Connor *et al*., 2004) and therefore a change at the pressure benchmark relates to a decrease in salinity to reduced (18-30 ppt) or variable (18-35 ppt).

The associated species *Corallina officinalis* and encrusting corallines are found in rockpools, such as this biotope, where salinities may fluctuate markedly during exposure to the air. In the Baltic, *Corallina officinalis* is confined to deeper waters as surface salinity decreases (Kinne, 1971), suggesting that full salinity is required in the long-term although short-term fluctuations may be tolerated (although the thresholds of this tolerance are not clear). Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons, so that a decrease in salinity at the pressure benchmark would be predicted to lead to reduced growth.

Edyvean & Ford (1984b) report that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

Based on occurrence in estuaries it is clear that some of the species associated with this biotope have a high tolerance for this pressure. *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are considered tolerant of decreases in salinity at the pressure benchmark.

Sensitivity assessment. Although some daily changes in salinity may be experienced these will be mitigated during tidal inundation. This biotope is considered, based on the distribution of *Osmundea pinnatifida*, *Corallina officinalis* and *Lithophyllum incrustans* to be sensitive to a decrease in salinity at the pressure benchmark. Resistance is therefore assessed as 'Low' and recovery as 'Medium-Low' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium-High' based on prolonged recovery of *Osmundea pinnatifida* turfs. The more precautionary assessment is presented in the table.

Water flow (tidal current) changes (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess the sensitivity of Osmundea pinnatifida to changes in water flow at the pressure benchmark. Biogenic habitat structures reduce the effects of water flows on individuals by slowing and disrupting flow. The fronds of *Osmundea pinnatifida* where these are dense will reduce the flow experienced by the turf. Boller and Carrington (2006), for example, found that the canopy created by the taller turf of *Chondrus cripsus* reduced drag forces on individual plants by 15-65%.

The crustose holdfasts of *Osmundea pinnatifida*, *Corallina officinalis* and the coralline crusts and and *Mastocarpus stellatus* petrocelis stage are securely attached and as these are relatively flat are subject less drag than upright fronds and are likely to tolerate changes in water flows at the pressure benchmark. Moderate water movement is beneficial to seaweeds as it carries a supply of nutrients and gases to the plants and removes waste products. However, if flow becomes too strong, plants may become dislodged.

An increase in water flow may inhibit settlement of spores and remove adults or germlings. However the red algae have a compact, turf forming growth which reduce water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow at the pressure benchmark. Decreased water flow may enhance sediment settlement in the turf and may result in less spores being removed. There is no evidence to suggests that either of these effects would negatively impact the biotope. Biotope resistance to increased and decreased water flow (at the pressure benchmark) is assessed as 'High' and resilience as 'High (by default) so that the biotope is assessed as 'Not sensitive'.

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

Emergence regime is a key factor structuring this (and other) intertidal biotopes. This biotope can be found below barnacles *Semibalanus balanoides* or red seaweed dominated communities, which include the species *Palmaria palmata*, *Corallina officinalis* or *Mastocarpus stellatus*. It is found above biotopes dominated by the wrack *Fucus serratus* and red seaweeds or above biotopes dominated by the kelp *Laminaria digitata* (Connor *et al*., 2004).

The associated *Patella vulgata*, *Semibalanus balanoides* and littorinids are found at a range of shore levels and are found in abundance at higher shore levels than this biotope typically occurs at. These species are therefore considered not to be affected by increased emergence. Experimental grazer removal has allowed red algae including *Palmaria palmata*, *Ceramium* sp. and *Osmundea* (as *Laurencia*) *pinnatifida* to grow higher on the shore during winter and damp summers (observations cited in Hawkins & Hartnoll, 1985) and to allow greater expansion of *Osmundea pinnatifida* turfs (Prathe, 2001) suggesting that grazing directly or indirectly is one of the factors limiting the upper shore extent of this biotope. An increase in grazers and grazing within this biotope associated with reduced predation level by crabs and predators following increased emergence may inhibit algae.

Environmental factors including irradiance and desiccation also limit the shoreward extend of turfs. *Osmundea pinnatifida* turfs growing on the upper extent of its usual zone in the Isle of Man experience greater desiccation and are shorter and less dense than those lower on the shore

(Prathep, 2001) suggesting that habitat quality (measured through growth) decreases with increasing shore height. In laboratory experiments short-term photosynthesis of *Osmundea pinnatifida* was inhibited where fronds had lost more than 50% of their water content (Prathep, 2001). Following resubmergence fronds that had lost 50 % of water content had fully recovered (measured as photosynthesis reaching maximal value) after 1 hour while fronds exposed to 70% water loss took 5 hours to recover (Prathep, 2001). Repeated exposure to high levels of desiccation would clearly impact growth.

In general red algae including *Osmundea pinnatifida* can tolerate low light levels and can extend into the subtidal. Decreased emergence will increase predation on grazers by crabs, starfish and other predators, reducing grazing pressure but support the growth of algae more suited to the emergence regime (typically fucoids kelps and *Alaria esculenta* depending on the shore height in relation to tidal changes).

Sensitivity assessment. Significant long-term increases in emergence would result in changes in environmental factors and grazing pressures and lead to increased competition from species better adapted to the changed conditions. Resistance to this pressure is therefore assessed as 'Low'. Resilience is assessed as 'Medium-Low' (where bases are removed) and sensitivity to this pressure is assessed as 'Medium-High' (the more precautionary assesment is presented in the table).

Wave exposure changes (local)	High Q: High A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Low

This biotope is recorded from locations that are judged to range from moderately exposed or exposed (Connor *et al*., 2004). The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch waves would be predicted to be higher. As this biotope occurs across a range of exposures, this was therefore considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark.

On exposed shores, larger more dense patches are better able to withstand increased wave action in winter than small patches which were severely damaged, presumably due to the number and density of stolons (Prathep, 2001)

Sensitivity assessment. The biotope is found across a range of wave exposures, mid-range populations are therefore considered to have 'High' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as 'High', by default, and the biotope is considered 'Not sensitive'.

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.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. Uptake of heavy metals from solution by seaweed is influenced by factors such as light, algal nitrogen content, frond age, length of emersion, temperature, salinity, season of the year and presence of other pollutants in the surrounding water (see Lobban & Harrison, 1997) and consequently seaweed may not accurately reflect metal concentrations in the surrounding water. No information was found concerning the effects of heavy metals on *Himanthalia elongata*, turf forming and encrusting coralline algae. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg> inorganic Hg > Cu > Ag > Zn> Cd>Pb. Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Little information was found concerning the intolerance of *Chondrus crispus* to heavy metals. Burdin & Bird (1994) reported that both gametophyte and tetrasporophyte forms accumulated Cu, Cd, Ni, Zn, Mn and Pb when immersed in 0.5 mg/l solutions for 24 hours. No effects were reported however, and no relationship was detected between hydrocolloid characteristics and heavy metal accumulation. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The sub-lethal effects of Hg (organic and inorganic) on the sporelings of an intertidal red algae, *Plumaria elegans*, were reported by Boney (1971), 100 % growth inhibition was caused by 1 ppm Hg.

Most of the information available suggests that adult gastropod molluscs are rather tolerant of heavy-metal toxicity (Bryan, 1984). Winkles may absorb metals from the surrounding water by absorption across the gills or from their diet and evidence from experimental studies on *Littorina littorea* suggest that diet is the most important source (Bryan *et al.*, 1983). The species has been suggested as a suitable bioindicator species for some heavy metals in the marine environment. Bryan *et al.* (1983) suggested that the species is a reasonable indicator for Ag, Cd, Pb and perhaps As. In the Fal estuary *Patella vulgata* occurs at, or just outside, Restronguet Point, at the end of the creek where metal concentrations are in the order: Zinc (Zn) 100-2000 µg/l, copper (Cu) 10-100µg/l and cadmium (Cd) 0.25-5µg/l (Bryan & Gibbs, 1983). However, in the laboratory *Patella vulgata* was found to be intolerant of small changes in environmental concentrations of Cd and Zn by Davies (1992). At concentrations of 10µg/l pedal mucus production and levels of activity were both reduced, indicating a physiological response to metal concentrations. Exposure to Cu at a concentration of 100 µg/l for one week resulted in progressive brachycardia (slowing of the heart beat) and the death of limpets. Zn at a concentration of 5500 µg/l produced the same effect (Marchan *et al.*, 1999).

The effects of tributyl tin (TBT), used in anti-fouling paints, on *Nucella lapillus* have been extensively documented and represent one of the best known examples of the effects of chemical pollution The following is based upon reviews by Hawkins *et al.* (1994) and Bryan & Gibbs (1991) to which the reader should refer for further detail.

- *Nucella lapillus* (and other stenoglossan gastropods) are particularly intolerant of TBT contamination. Imposex is initiated at TBT concentrations low as <0.5 µg Sn/l. A proportion of females are sterilised at 1-2 µg Sn/l, and virtually all females are sterile at 3-5 µg Sn/l. Oogenesis was suppressed at >10 µg Sn/l, testis development may occur at 20 ng Sn/l and the sperm ingesting gland in some females remains undeveloped at 100 µg Sn/l (Gibbs *et al.*, 1988; Hawkins *et al.*, 1994). These values can be compared with concentrations of 430 µg Sn /l in the Crouch estuary and >2 µg Sn/l in some marine sites (Waldock & Miller, 1983).
- *Nucella lapillus* has been effectively exterminated from many areas in its European range (Gibbs *et al.*, 1991), especially in area of pleasure boating or shipping. In the south coast of England virtually all populations had been affected to some extent, and some were extinct

(Bryan & Gibbs, 1991; Hawkins *et al.*, 1994).
- Imposex is irreversible and recovery is dependant on recruitment of juveniles into the population.
- TBT has been banned from use of boats <20 m since 1987 since which time populations have begun to recover.
- Evans *et al.* (1996b) reported marked recovery of many populations from the North Sea and Clyde Sea and that although ports were 'hot spots' of TBT contamination the populations of *Nucella lapillus* were not sterile and produced enough offspring to survive. However, several populations is semi-enclosed areas with high boating activity in south west England had become extinct. Evans *et al.*, (1996b) also suggested that extinction of populations in Tarbert Harbour, western Scotland, the Clyde Sea, Lerwick in Shetland, the Solent, Channel Islands, Isle of Wight and east coast of the North Sea were probably due to TBT contamination.
- Moore *et al.* (2000) reported recovery of *Nucella lapillus* from the effects of TBT contamination in Yell Sound, adjacent to the Sullom Voe oil terminal in Shetland, with only 28 % of females showing signs of imposex in their 1999 survey. The population in Sullom Voe itself, especially close to the terminal, had improved since 1991 but still had a low reproductive capacity.

Overall, *Nucella lapillus* is highly sensitive of TBT contamination, while females may be killed at concentrations above 5 µg Sn/l, imposex and hence reduced reproductive capacity can occur at lower concentration (above) and the population will decline due to natural mortality and poor recruitment. Where populations have become extinct, recovery is dependant on recolonization, and may take many years due to their poor dispersal capability (see additional information below). Bryan & Gibbs, (1991) and Hawkins *et al.* (1994), note that TBT is persistent in sediments and little recovery is likely until the ambient concentration of TBT falls below 4 µg/l.

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.

Himanthalia elongata survived the *Torrey Canyon* oil spill and indeed extended 2 m vertically up the shore, due to the absence of grazers (Southward & Southward, 1978). The species lives in the lower eulittoral and sublittoral fringe, which means that oil will rapidly be washed off the fronds. It also usually occurs in areas with strong currents, allowing oil to be rapidly dispersed.

O'Brien & Dixon (1976) stated that red algae were the most sensitive group of algae to oil contamination especially in combination with dispersant contamination, possibly due to the susceptibility of the photosynthetic pigment phycoerythrin to chemical damage. Filamentous forms are considered to be most sensitive. Observations following oil spills indicate that grazing species are particularly intolerance of oil pollution. Following the *Torrey Canyon* oil spill in 1967, oil and detergent dispersants affected high shore specimens of *Corallina officinalis* more than low shore specimens. Plants in deep pools were afforded some initial protection, although probably later affected by contaminated runoff. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith 1968).

Thick layers of deposited oil would probably interfere with respiration and spoil food supplies for *Patella vulgata*. Limpets are unable to remain 'closed-off' from the environment for very long, and the adductor muscles relax occasionally, lifting the shell very slightly exposing the animal to contaminants. After the *Braer* oil spill, in common with many other oil spills, the major impact in the intertidal zone was on the population of limpets and other grazers. In West Angle Bay, where fresh oil from the *Sea Empress* tanker reached rocky shores within one day of the spill, limpet mortality was 90 % (Glegg *et al*., 1999). In the case of the *Torrey Canyon* spill the quantity and toxicity of the oil dispersants applied to the shore caused more mortalities than the oil alone, *Patella vulgata* being particularly susceptible, although all animals and many algae were killed in areas heavily sprayed (Raffaelli & Hawkins, 1996). Following oil pollution rocky shore communities are highly disturbed owing to the loss of structuring species. The recovery period can be extensive owing to both loss of species and the subsequent extreme fluctuations in abundance. In the *Torrey Canyon* incident, following the death of grazing species, a dense green flush of ephemeral algae (*Blidingia* & *Ulva*) developed and lasted for nearly a year, whilst after six months *Fucus vesiculosus* and *Fucus serratus* began to colonize the shore and persisted in dense stands for between 1 to 3 years. *Patella vulgata* colonized affected shores within the year and thrived in damp conditions under the fucoids, its grazing inhibited further extensive fucoid recruitment. Abnormal numbers of limpets accrued and cleared rocky substrata of much of the algae, allowing, after a period of 4 years (in dispersant treated areas), increased barnacle recruitment. Fucoid cover remained abnormal for the first 11 years following the spill and fluctuated for 15 years, whilst the population structure of *Patella vulgata* remained abnormal for at least 10 years (Smith, 1968; Southward & Southward, 1978; Hawkins & Southward, 1992). In longer term studies into the environmental effects of oil refinery effluent discharged into Littlewick Bay, Milford Haven, the number of limpets, usually found in substantial numbers on this type of shore, were considerably reduced in abundance on areas close to the discharge (Petpiroon & Dicks, 1982). In particular only large individuals were found close to the outfall point and juveniles were completely absent, suggesting that observed changes in abundance resulted from effluent effects on larval stages rather than upon adults directly.

The combination of oiling and subsequent treatment with dispersants after the *Torrey Canyon* oil spill (in March 1967) resulted in loss of *Nucella lapillus* from affected shores, however, Smith (1968) noted that where less dispersants were used *Nucella lapillus* was amongst one of the most tenacious gastropods. Smith (1968) noted that the most resistant gastropods (such as *Phorcus lineatus* and to a lesser extent *Nucella lapillus*) were able to tightly close their shells with their operculum. The toxicity of the emulsifiers BP1002 (a non-ionic surfactant in an aromatic hydrocarbon solvent) has been examined by several workers. Smith (1968) reported that 10 ppm was adequate to inhibit crawling in gastropods and that *Nucella lapillus* was detached at this concentration. A concentration of >100 ppm was required to kill the majority of the dog whelk (after 24hr exposure at 12°C). Bryan (1968) noted that none died when exposed to 1ppm BP1002 and some survived longer than 2 hrs in neat BP1002. BP1002 was most toxic between 2.5-1000 ppm but less so above 1000ppm since the dog whelk was able to detect the emulsifier and close its shell. Surviving individuals recovered within 8 days. Crapp (1970a) reported that *Nucella lapillus* was severely affected by direct treatment with BP1002 in the field (exposed for ca. 6hrs at low tide). However, Crapp (1970b) reported that *Nucella lapillus* was relatively resistant, exhibiting a 1 hr LC_{50} of between 10,000 -500,000 ppm, depending on season, being very resistant in winter. Crapp (1970b) also noted that individuals took longer to recover from exposure in winter. Exposure to petrol/water emulsions in Milford Haven as a result of the *Dona Marika* incident, caused gastropods to retract into their shells and resulted in a marked reduction in *Nucella lapillus* abundance, from Common to Rare. However, numbers increased within 9-11 months, mainly due to recolonization by adults that had presumably been narcotized or retracted, washed below low water and had taken some time to recover before returning to the shore (Blackman *et al*., 1973; Baker, 1976). Smith (1968) and Bryan (1968) report similar rapid re-colonization from low water. Bryan (1968) noted that the majority of the recruitment was by juveniles that had presumably been living below low water during the spill and that the population had recovered within 2 years. However, both Smith (1968) and Bryan (1968) suggested that in areas of heavy treatment by dispersants, recovery may take much longer.

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.

Contamination at levels greater than the benchmark may result in impacts on the biotope. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also report that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentration of detergent. Smith (1968) reported that 10 ppm of the detergent BP 1002 killed the majority of specimens in 24hrs in toxicity tests, although *Chondrus crispus* was amongst the algal species least affected by the detergent used to clean up the *Torrey Canyon* oil spill. Laboratory studies of the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages (Grandy, 1984, cited in Holt *et al*., 1995). Cole *et al*. (1999) suggested that herbicides, such as simazine and atrazine, were very toxic to macrophytes. The evidence suggests that in general red algae are very sensitive to synthetic chemicals.

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 was found to assess this pressure at the benchmark. Algae bioaccumulate radionuclides (with extent depending on the radionuclide and the algae species). Adverse effects have not been reported at low levels.

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: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The effects of reduced oxygenation on algae are not well studied. Plants require oxygen for respiration, but this may be provided by production of oxygen during periods of photosynthesis. Lack of oxygen may impair both respiration and photosynthesis (see review by Vidaver, 1972). A study of the effects of anoxia on another red alga, *Delesseria sanguinea* revealed that specimens died after 24 hours at 15°C but that some survived at 5°C (Hammer, 1972). This biotope would only be exposed to low oxygen in the water column intermittently during periods of tidal immersion. In addition, in areas of wave exposure and moderately strong current flow low oxygen levels in the water are unlikely to persist for very long as oxygen levels will be recharged by the incorporation of oxygen in the air into the water column or flushing with oxygenated waters.

No evidence was found to assess this pressure for the red algae turfs. However, the associated species are unlikely to be impacted by this pressure, at the benchmark. Experiments have shown that thallus discs of *Ulva lactuca* plants can survive prolonged exposure to anoxia and hypoxia (Vermaat & Sand-Jensen, 1987; Corradi *et al.*, 2006). Following resumption of normal oxygen conditions gametes were produced. The associated invertebrate species also show high tolerances for reduced oxygen at levels that exceed the pressure benchmark. *Littorina littorea* can easily survive 3-6 days of anoxia (Storey *et al.*, 2013). *Semibalanus balanoides* can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al.*, 1963). Limpets can also survive for a short time in anoxic seawater; Grenon & Walker, (1981) found that in oxygen free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. *Patella vulgata* and *Littorina littorea* are able to respire in air, mitigating the effects of this pressure during the tidal cycle.

Sensitivity assessment. No direct evidence for the effects of hypoxia on red algal turfs was found. As the biotope will only be exposed to this pressure when emersed and respiration will occur in air, biotope resistance was assessed as ‘High’ and resilience as ‘High’ (no effect to recover from), resulting in a sensitivity of 'Not sensitive'.

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The pressure benchmark is set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014).

Marine algae are often nutrient limited, by nitrogen in particular, so an increase in nutrient levels usually results in increase growth and fecundity. In the Bay of Fundy, for example, where there is a tidal flux of nutrients from the marshes there is luxurious growth of *Palmaria palmata*. However, very high levels of nutrients can be toxic to macroalgae. Plants placed in tanks with continuous immersion in high nutrients over several weeks stopped growing (Morgan *et al.*, 1980). In general, the great majority of reports refer to an increase in the number of green algae associated with eutrophicated waters, usually at the expense of red and brown algae.

Atalah & Crowe (2010) added nutrients to rockpools. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. The rockpools were occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. Nutrients had no significant effect on the cover of crustose coralline algae or the cover of red turfing algae (Atalah & Crowe, 2010). However, the cover of green filamentous algae increased where grazers were removed (Atalah & Crowe, 2010). The study suggests that, although red algal turfs may be tolerant of eutrophication and may even benefit, biotope composition may alter due to the proliferation of fast growing ephemeral algae.

Sensitivity assessment. The pressure benchmark is set at a level that is relatively protective and based on the evidence and considerations outlined above the biological assemblage is considered to be 'Not sensitive' at the pressure benchmark. Resistance and resilience are therefore assessed as 'High'.

Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

As this biotope occurs in wave exposed areas it is considered unlikely to be exposed to the build-up of organic matter (at the pressure benchmark) as wave action will remove organic deposits. The effects of sedimentation of organic matter are therefore not considered relevant to this biotope. Organic enrichment and nutrient enrichment commonly co-occur, for example sewage deposits or outputs from fish farms may enhance nitrogen and phosphorous and organic matter. The effect of inorganic nutrients has more effects on algal communities than organic matter which is not assimilated (see nutrient enrichment).

Deposit and filter feeders within the biotope such as *Mytilus edulis* and *Semibalanus balanoides* may benefit from increased organic matter where this can be used as food. Cabral-Oliveira *et al.*, (2014), found higher abundances of juvenile *Patella* sp. and lower abundances of adults closer to sewage inputs, Cabral-Oliveira *et al.*, (2014) suggested the structure of these populations was due to increased competition closer to the sewage outfalls.

Sensitivity assessment. Based on resistance to sedimentation, it is judged that this biotope has 'High' resistance to increased organic matter at the pressure benchmark (which represents enrichment rather than gross pollution). Resilience is therefore assessed as 'High' (no effect to recover from) and the biotope is considered to be 'Not sensitive'.

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 and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). 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.

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

The loss of hard substratum would remove the rockpool habitat and sediments would be unsuitable for the red algal turf, crustose corallines and other attached algae that characterize this biotope. Other associated species such as anemones and limpets would also be lost as these are associated with rock habitats. Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2013) or the presence of non-native species (Bulleri & Airoldi, 2005). The presences of small crevices that prevent grazing and limit the effects of desiccation and other environmental factors such as exposure to wave action and currents appears to be critical to the establishment of turfs (Prathep, 2001). Smooth, homogenous substrata would not be suitable for recruitment and would not replace natural habitats.

Sensitivity assessment. Based on the loss of suitable habitat resistance is assessed as 'None' recovery is assessed as 'Very Low' as the change at the pressure benchmark is permanent. Sensitivity is therefore 'High'.

Physical change (to another sediment type)	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 to biotopes occurring on bedrock.

Habitat structure changes - removal of substratum (extraction)	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

The species characterizing this biotope are epiflora and epifauna occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

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

The species characterizing this biotope occur on the rock and therefore have no shelter from abrasion at the surface. No direct evidence was found to assess abrasion impacts on the key characterizing species *Osmundea pinnatifida*. Abrasion can remove the frond of red and brown algae although experimental results vary. Experimental results and observations of trampled vs non-trampled areas have shown that turf-forming algal species are relatively resistant to this pressure and may increase in abundance where foliose and canopy forming species are removed. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf forming algae were relatively resistant. Brosnan (1993) noted that algal turf species (*Endocladia muricata* and *Gelidium* spp.) increased by 38% in trampled plots as foliose algae declined, and algal turf dominated trampled areas. Exclusion of visitors, and hence reduced trampling, reduced relative algal turf abundance by 31%, while foliose algae increased in abundance. Schiel & Taylor (1999) observed a decrease in understorey algae (erect and encrusting corallines) after 25 or more tramples, probably due to an indirect effect of increased desiccation as above. However, Schiel & Taylor (1999) did not detect any variation in other algal species due to trampling effects and Keough & Quinn (1998) did not detect any effect of trampling on algal turf species.

Littler & Kauker, (1984) suggest that the basal crustose stage of *Corallina officinalis* is adaptive to resist sand scour and wave shearing (as well as physiological stressors such as desiccation and heating). The base is much tougher than the fronds, as shown by experiments that demonstrate that the base has nearly twice the mechanical resistance (measured by penetration) of fronds (Littler & Kauker, 1984). The crustose bases of *Osmundea pinnatifida* and the petrocelis stage of *Mastocarpus stellatus* are also likely to have a greater resistance to abrasion pressures than the fronds.

In general, studies show that *Corallina* and other turf forming algae appear to be relatively resistant to single events and low levels of trampling. Similarly, a comparison of rocky intertidal ledges that received different amounts of visitors in Dorset, England, found that *Corallina officinalis* were present on both heavily visited and less visited ledges suggesting that this species has some resistance to trampling (Pinn & Rodgers, 2005). Povey & Keough (1991) in Mornington Peninsula, Australia investigated the effects of sustained trampling on intertidal coralline algal mats where upright branching *Corallina* spp. formed a turf with other red algae with sand and encrusting coralline algae between turfs. The experimental strips were 2 m long and 0.5 m wide. The percentage cover of upright *Corallina* spp. was significantly affected by 25 passages of a strip per day after 12 and 33 days. The algae appeared flattened and were shorter (1-2 cm high) compared with the low intensity and control plots (3-4 cm high). Overall cover of coralline turfs rose by 3% in trampled sites and by 11% in non-trampled sites compared to controls. Low intensity trampling within a strip (2 passages/ day) did not significantly affect the coralline turf. Brown & Taylor (1999) found that higher intensities of trampling damaged turfs. Moderate (50 steps per 0.09 m^2) or more trampling on intertidal articulated coralline algal turf in New Zealand reduced turf height by up to 50 % and reduced the weight of sand trapped within turf to about one third of controls. This resulted in declines in densities of the meiofaunal community within two days of trampling. Although the community returned to normal levels within 3 months of trampling events, it was suggested that the turf would take longer to recover its previous cover (Brown & Taylor, 1999). Similarly, Schiel & Taylor (1999) noted that trampling had a direct detrimental effect on coralline turf species on the New Zealand rocky shore. At one site coralline bases were seen to peel from the rocks (Schiel & Taylor, 1999), however, this was probably due to increased desiccation caused by loss of the algal canopy.

The barnacles, limpets and littorinids that occur in this biotope, have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Removal of limpets and barnacles may result in these being displaced to a less favourable habitat and injuries to foot muscles in limpets may prevent reattachment. Although limpets and littorinids may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of abrasion are provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles.

The effects of trampling on barnacles appears to be variable with some studies not detecting significant differences between trampled and controlled areas (Tyler-Walters & Arnold, 2008). However, this variability may be related to differences in trampling intensities and abundance of populations studied. The worst case incidence was reported by Brosnan & Crumrine (1994) who found that a trampling pressure of 250 steps in a 20x20 cm plot one day a month for a period of a year significantly reduced barnacle cover (*Semibalanus glandula* and *Chthamalus dalli*) at two study sites. Barnacle cover reduced from 66 % to 7 % cover in 4 months at one site and from 21 % to 5 % within 6 months at the second site. Overall barnacles were crushed and removed by trampling. Barnacle cover remained low until recruitment the following spring. Long *et al*. (2011) also found that heavy trampling (70 humans/km/hr) led to reductions in barnacle cover. Single step experiments provide a clearer, quantitative indication of sensitivity to single events of direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victoria, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamlus antennatus* about 3mm long), were crushed. However, on the same shore, the authors found that limpets may be relatively more resistant to abrasion from trampling. Following step and kicking experiments, few individuals of the limpet C*ellana trasomerica*, (similar size to *Patella* *vulgata*) suffered damage or relocated (Povey & Keough, 1991). One kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). On the same shore less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991).

Shanks & Wright (1986), found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could create patches in aggregations of the barnacle, *Chthamalus fissus*, and could smash owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40% lower than at a sheltered site. Severe storms were observed to lead to almost total destruction of local populations of limpets through abrasion by large rocks and boulders. In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al*., 2006).

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Resistance, to a single abrasion event of *Osmundea pinnatifida* and the associated red algal turf and barnacles, limpets and littorinids is assessed as 'Medium' (<25% of population damaged or removed) as some damage to individuals and fronds of algal turfs may be removed although the bases may remain. Recovery is 'High', through regrowth of fronds from crustose bases, so that sensitivity is assessed as 'Low'. Resistance and resilience will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force and remove the bases of algal turfs and damage and remove a greater proportion of species.

Penetration or disturbance of the substratum subsurface	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

The species characterizing this biotope group are epiflora and epifauna occurring on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure.

Changes in suspended solids (water clarity)	High Q: High A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Low

Intertidal biotopes will only be exposed to this pressure when submerged during the tidal cycle and thus have limited exposure. Siltation, which may be associated with increased suspended solids and the subsequent deposition of these is assessed separately (see siltation pressures). In general, increased suspended particles reduce light penetration and increase scour and deposition. They may enhance food supply to filter or deposit feeders (where the particles are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts).

Increases in the cover of sediment trapping, turf forming algae at the expense of canopy forming species has been observed worldwide in temperate systems, and has been linked to increased suspended solids linked to human activities (Airoldi, 2003). As turfs of *Osmundea pinnatifida* trap sediments (Prathep *et al*., 2003) it is clear that this specie has some resistance to abrasion and scour from sediment particles. An accumulation of sediment within the turf may attract more sediment dwelling interstitial invertebrates such as nematodes, harpacticoids and polychaetes, although in more wave exposed locations accumulation of sediment is likely to be minimal.

Increased suspended sediment may also result in increased scour, which may adversely affect foliose red algae, and interfere with settling spores and recruitment if the factor is coincident with their major reproductive period. However, coralline algae, especially the crustose forms and most likely the crustose holdfasts of other algal turf forming species, including *Osmundea pimnnatifida* and the petrocelis stage of *Mastocarpus stellatus* are likely to be resistant of sediment scour (Littler & Kauker, 1984) and regeneration will not be dependent on settlement.

This community is unlikely to be dependent on suspended sediment. Although accumulated sediment within coralline turf habitats is likely to increase the species diversity of the epiphytic fauna, in very wave exposed locations, accumulated sediment in the habitat is likely to be minimal. A reduction in suspended sediment will probably reduce the risk of scour, and reduce food availability for the few suspension feeding species in the biotope (e.g. barnacles and spirorbids present), although effects are not likely to be lethal.

The biotope occurs in the intertidal where light attenuation due to increases in turbidity is probably low. Red algae and coralline algae especially are known to be shade tolerant and are common components of the understorey on seaweed dominated shores. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels (Prathep, 2001).

Sensitivity assessment. The exposure of biotope to suspended sediments in the water column will be limited to immersion periods, and wave action will reduce accumulation. The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles and other filter and deposit feeders that occur in this biotope. An increase in suspended solids may lead to some sub-lethal abrasion of fronds however, evidence globally indicates that increase suspended solids favour the turf-forming algae that characterize this biotope (Airoldi, 2003). Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'. An increase in suspended solids above the pressure benchmark may result in a change in species composition with an increase in species seen in very turbid, silty environments e.g. *Ahnfeltia plicata*, *Rhodothamniella floridula*, *Polyides rotunda* and *Furcellaria lumbricalis*.

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

Sedimentation can directly affect assemblages inhabiting rocky shores in different ways but particularly by the burial/smothering and scour/abrasion of organisms. This biotope occurs in habitats that are moderately exposed or exposed to wave action (Connor *et al*., 2004). In areas with greater water flow or wave action, excess sediments will be removed from the rock surface within a few tidal cycles, reducing the time of exposure to this pressure. Turfs of *Osmundea pinnatifida* trap sediments (Prathep et al., 2003) suggesting that this specie has some resistance to abrasion and scour from sediment particles.

The fronds of *Osmundea pinnatifida* are short and upright and most will be covered by 5cm depth of sediment. The state of the tide will mediate the degree of impact on other associated macroalgae. If smothering occurs at low tide when the associated algae are lying flatter on the substratum, then most of the organism as well as the associated community will be covered by the deposition of fine material at the level of the benchmark. Smothering will prevent photosynthesis resulting in reduced growth and eventually death. If however smothering occurs whilst the alga is submerged standing upright then the photosynthetic surfaces of taller adult plants will be left uncovered. The resistance of this biotope to the given pressure may therefore vary with according to the tide and timing of deposition. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Devinny & Volse, 1978; Eriksson & Johansson, 2003; Berger *et al*. 2003; Vadas *et al*., 1992; Airoldi, 2003). Intermittent exposure to silt and coarser sediments may be tolerated by mature plants.

Increased abundance of algal turfs worldwide has been linked to sediment perturbations although not all the pathways and mechanisms of these effects are clear (see review by Airoldi, 2003). However, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have has not been identified (Airoldi, 2003). The associated species *Corallina officinalis* and others within the genus (e.g. *Corallina pinnatifolia* and *Corallina vancouveriensis*) are found on shores subject to high rates of sedimentation that are periodically disturbed by sand burial and scour (Stewart, 1989). Coralline turfs also trap sediments within the turf. The amount of sediment present and the associated fauna varies naturally depending on local conditions such as wave exposure (Dommasnes, 1969). On intertidal shores in southern California the amount of sediment trapped within turfs of *Corallina* spp. varied seasonally from < 5mm to >4.5 cm and was closely related to species composition and the structure of the turf. Airoldi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by *Osmundea pinnatifida* and *Corallina* spp are the regeneration of upright fronds from a perennial basal crust resistant to burial and scour,, apical meristems, lateral vegetative growth and slow growth rates (Airoldi, 2003). Experimental deposition of sand on coralline turfs and maintained at 3cm or 6 cm for one month via daily top-ups did not remove the turfs but did lead to rapid (within 1 hours changes in the invertebrate species as highly mobile species moved away from the turf with later colonisation by sand adapted species (Huff & Jarett, 2007). The community had recovered one month after sand deposition ceased (Huff & Jarett, 2007).

Atalah & Crowe (2012) added sediment to rockpools to test the effects of sedimentation experimentally. The rockpools were occupied by a range of algae including encrusting corallines and turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Sediment treatments involved the addition of a mixture of coarse and fine sand of either 300 mg/cm^2/month or 600 mg/cm^2 every 15 days. The treatments were applied for seven months and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools the chronic addition of both levels of sediment led to a significant increase in the cover of *Corallina officinalis*, green filamentous algae (*Ulva* sp.) and red turfing algae while crustose coralline algae decreased. Sedimentation led to an increase in the mean cover of red turfing algae (*Mastocarpus stellatus* and *Chondrus crispus* and *Corallina officinalis*) from 11.7% (±1.0 S.E.) in controls to 26.1% (±4.7 S.E.) in sedimented assemblages, but there were no differences between the two levels of sedimentation (Atalah & Crowe, 2010). The results suggest that some of the species found in this biotope (Corallina officinalis and Mastocarpus stellatus) are tolerant of chronic levels of low sedimentation.

The associated species, *Patella vulgata* and *Littorina* spp. are likely to be negatively affected by siltation (Airoldi & Hawkins, 2007; Chandrasekara & Frid,1998; Albrecht & Reise, 1994). Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit limpet grazing and result in loss of attachment and death after a few days Airoldi & Hawkins (2007). The laboratory experiments are supported by observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England, as *Patella vulgata* abundances were higher where deposits were absent (Airoldi & Hawkins, 2007). Littler *et* *al*., (1983) found that the another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. Deposition of 5 cm of fine material (see benchmark) in a single incident is unlikely to result in significant mortality before sediments are removed by current and wave action. Burial will lower survival and germination rates of spores and may lead to some mortality of spores and early stages of foliose red algae. Adults are more resistant but will experience a short-term decrease in growth and photosynthetic rates. Resistance is assessed as 'Medium' based on rapid removal of the majority of smothering sediments within a couple of tidal cycles, resistance will be lower where sediment remains in place for longer. Resilience is assessed as 'High' as crustose bases of the characterizing red algae will remain and regeneration and vegetative growth will repair turfs. Overall the biotope is considered to have 'Low' sensitivity to smothering at the level of the benchmark. It should be noted that the associated *Patella vulgata* and littorinids have higher sensitivities to this pressure and that removal of these species may result in changes in algal composition and abundances through indirect grazing effects. Increased chronic siltation may lead to changes in assemblage and replacement by species more tolerant of scour such as *Rhodothamniella floridula*. Confidence in the assessment is 'Low' due to the lack of direct evidence for the key characterizing species *Osmundea pinnatifida*.

Smothering and siltation rate changes (heavy)	Low Q: Low A: NR C: NR	High Q: High A: Low C: High	Low Q: Low A: Low C: Low

Sensitivity to this pressure will be mediated by site-specific hydrodynamic conditions and the footprint of the impact. Where a large area is covered sediments may be shifted by wave and tides rather than removed. However, mortality will depend on the duration of smothering, where wave action rapidly mobilises and removes fine sediments, survival may be much greater. No evidence was found to assess this pressure at the benchmark, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have has not been identified (Airoldi, 2003).. A deposit at the pressure benchmark would cover species with a thick layer of fine materials, however, as this biotope occurs in the mid-intertidal it is subject to prolonged immersion and silts may be relatively rapidly re-suspended and removed.

Species associated with this biotope such as limpets and littorinids would not be able to escape from deposits and would likely suffer mortality (see evidence for light siltation).

Sensitivity assessment. At the level of the benchmark (30 cm of fine material added to the seabed in a single event) smothering is likely to result in mortalities of macroalgae, particularly germlings, and invertebrate grazers. Resistance is assessed as 'Medium-Low' as many individuals exposed to siltation at the benchmark level are predicted to die and resilience is assessed as 'High' as crustose bases of the red algae turf forming species are likely to survive and provide a mechanism for recovery through vegetative growth. Overall the biotope has a 'Low' sensitivity to siltation at the pressure benchmark, based on rapid recovery. It should be noted that the associated *Patella vulgata* and littorinids may have higher sensitivities to this pressure and that if these species are removed over a large area, changes in algal composition and abundance may result and are likely to include a greater abundance of green algae until grazing levels are re-established. Confidence in the resistance is assessed as 'Low' due to the lack of evidence for sedimentation at the pressure benchmark.

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	No evidence (NEv) 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	High Q: High A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Low

Red algae frequently occur subtidally or as turfs beneath canopy forming brown algae. They are therefore adapted to low light conditions. Prathep (2001) observed higher growth rates of *Osmundea pinnatifida* turfs on the Isle of Man in winter when irradiance was lowest (average 28 μmol/m^2/s). In summer when irradiance was higher (average 1194 μmol/m^2/s) fronds were bleached. Photoinhibition of photosynthesis was observed in submerged plants at irradiances of 1200 μmol/m^2/s and some tips became bleached after exposure for 35-40 minutes (Prathep, 2001). Experimental tests established that irradiance rather than desiccation resulting from higher temperatures is responsible for the observed bleaching. Artificial shades placed above *Osmundea pinnatifida* turfs occurring on Isle of Man shores for 1 month (mid-April-mid-March) did not reduce dessication but no bleaching occurred in shaded turfs (compared to unshaded) indicating that irradiance, rather than desiccation results in the observed bleaching of fronds (Prathep, 2001). Removal of fucoid canopies has also been observed to result in bleaching of understorey turfs of *Osmundea pinnatifida* (Prathep, 2001). Shaded turfs can acclimate to lower light levels by producing more phycobilins which allow for more efficient light capture (Prathep, 2001).

Sensitivity assessment. Based on shade tolerance of *Osmundea pinnatifida* and other red algal turf forming species and ability to acclimate to higher light levels, biotope resistance is assessed as 'High' and resilience as 'High' so that the biotope is considered to be 'Not sensitive'.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. Barriers and changes in tidal excursion are not considered relevant to the characterizing red algal species as dispersal is limited by the rapid rate of settlement and the biotope is maintained by vegetative growth from bases rather than reliance on recruitment from outside of populations. Other species associated with the biotope are widely distributed and produce large numbers of larvae capable of long distance transport and survival, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

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' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion.

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	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

No information was found on current production of *Osmundea pinnatifida*, *Mastocarpus stellatus* or other turf forming red seaweeds in the UK and it is understood that wild harvesting rather than cultivation is the method of production for this species and littorinids. No evidence was found for the effects of gene flow between cultivated species and wild populations. Although cultivation of different genotypes may lead to gene flow between wild and cultivated populations the limited dispersal may reduce exposure. Some negative effects may arise from hybridisation between very geographically separated populations but there is no evidence to suggest that gene flow between different UK haplotypes would lead to negative effects. This pressure is therefore considered 'Not relevant' to this biotope group.

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

Invasive non-indigenous species (INIS) that can alter habitats (ecological engineers), or out-compete native macroalgae for space and other resources such as light and nutrients, are the most likely species to negatively affect this biotope. Space pre-emption by encrusting corallines and the crustose bases of the macroalgae forming the turf, as well as the trapped sediment within the turf, may prevent settlement of INIS until disturbance events create gaps for invasion. However, in the Mediterranean crustose corallines and algal turfs facilitate attachment of the INIS *Caulerpa racemosa* by providing a more complex substratum than bare rock (Bulleri & Benedetti-Cecchi, 2008).

Algal species which may have overlapping habitat requirements include the green seaweed *Codium fragile* subsp *tormentosoides* (now renamed as *Codium fragile fragile*) and the red seaweed *Heterosiphonia japonica*, neither of these have so far been recorded in nuisance densities (Sweet, 2011j). Wireweed, *Sargassum muticum*, grows best on sheltered shores and in rockpools (Sewell, 2011c) and the wave exposed habitats where this biotope occurs may not be suitable for establishment.

The morphologically similar, red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain; however this large, fast-growing seaweed may have the potential to displace native seaweed species and shade neighbouring species. In North America this species is a major competitor of *Chondrus crispus* which provides an important winter food source for littorinids and other invertebrates. As *Grateloupia turuturu* dies-back in the winter, the dispolacement of other species may therefore affect grazers (Sweet, 2011g).

The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumyota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2011b and 2012b). A significant potential INIS is the Pacific oyster *Magallana gigas*, as its distribution and environmental tolerances are considered to overlap with this biotope and this reef forming species can alter habitat structure. This species may also affect the grazers present in the biotope.

The non-native crab *Hemigrapsus sanguineus* has recently been recorded in the UK (Sweet & Sewell, 2014) and has the potential to be a significant predator of intertidal invertebrates. Significant reductions in common shore crab abundance and mussel density have been reported where the Asian shore crab has achieved high densities in mainland Europe (Sweet & Sewell, 2014). In Rye, New York, declines of approximately 80% of *Littorina littorea* in the intertidal were reported to coincide with an expansion of the *Hemigrapsus sanguineus* population (Kraemer *et al*., 2007). This crab occurs on exposed shores and may therefore occur in this biotope when established.

Sensitivity assessment. Little evidence was found to assess the impact of INIS on this biotope and much of the evidence comes from intertidal habitats in other countries. The conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact. Replacement of red algal turfs by other similar species may lead to some subtle effects on local ecology but at low abundances the biotope would still be recognisable from the description. Based on *Crassostrea gigas* resistance to this pressure is assessed as ‘Low’. The biotope will only recover if these species are removed, either through active management or natural processes. To recognise that recovery may be prolonged, resilience is assessed as ‘Very Low’ and sensitivity is therefore assessed as ‘High’.

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

No evidence was found for pathogens of *Osmundea pinnatifida*. Other species associated with this biotope such as littorinids, patellid limpets and other algae also experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona sp*, which weakens the shell and increases crab predation.

Sensitivity assessment. Based on the lack of evidence for major pathogens or significant mortalities of *Osmundea pinnatifida* this biotope is considered to have 'High' resistance and hence 'High' resilience and is classed as 'Not sensitive' at the pressure benchmark.

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

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 target species on this biotope. Incidental removal of the key characterizing species and associated species would alter the character of the biotope. Harvesting of *Osmundea pinnatifida* for drying and use as a spice occurs primarily in Scotland, Ireland, and on the Atlantic coast of Canada (www.seaweedindustry.com).

Corallina officinalis is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.* 1987). It is also sold as a powder for use in the cosmetic industry. The red algae *Mastocarpus stellatus* and *Chondrus crispus* are both harvested commercially in Scotland and Ireland, the stipe is removed but the base is left intact to allow the algae to re-grow. The effect of harvesting *Chondrus crispus* has been best studied in Canada. Prior to 1980, the seaweed beds of Prince Edward Island were dominated by *Chondrus crispus* and the species was heavily exploited. Recently, there has been a marked increase in abundance of another red seaweed, *Furcellaria lumbricalis*, which is avoided by the commercial harvest, and an associated decline in abundance of *Chondrus crispus* (Sharp *et al*., 1993). The authors suggested that harvesting has brought about the shift in community structure. *Palmaria palmata* (known as dulse) is harvested from the wild for human consumption both commercially and recreationally. Garbary *et al*., (2012) studied harvested and non-harvested shores in Nova Scotia, Canada containing stands of *Palmaria palmata*. They also conducted experimental removal of *Palmaria palmata* and assessed simulated removal of *Palmaria palmata* by an experienced commercial harvester. Simulated commercial harvesting reduced cover of *Palmaria palmata* from 70% to 40%, although experimental removal on shores not usually harvested reduced cover to 20% (Garbary *et al*., 2012). These studies indicate that targeted harvesting of red algae is effectively reduced turf cover.

The winkle *Littorina littorea* and the limpet *Patella vulgata* occur in this biotope and may be gathered by hand. Changes in grazer abundance can alter the character of the assemblage. Grazer removal (manual removal of all gastropods in pool and a 1m surrounding perimeter) caused strong and highly significant changes in assemblage structure in rockpools that contained red turf forming algae mainly due to an increase in the cover of green filamentous algae and a decrease in cover of live crustose coralline algae (25.40%) (Atalah & Crowe, 2010).

The removal of kelps or fucoids from this biotope would reduce shading and is not considered to negatively affect this biotope (for assessment of removal of the key characterizing species as by-catch, see the removal of non-target species pressure).

Sensitivity assessment. The species that are harvested in this biotope are all attached, sedentary or slow moving and relatively conspicuous. A single event of targeted harvesting could therefore efficiently remove individuals and resistance is assessed as 'Low' supported by evidence from other red algae species. No evidence was available for the proportion of *Osmundea pinnatifida* removed by experienced harvesters and harvesting may be carried out sustainably by only harvesting a small proportion of fronds. Resilience of the turf forming red seaweeds is assessed as ‘High’ (based on evidence for recovery from harvesting that did not damage the algal bases, see resilience section) and biotope sensitivity is assessed as ‘Low'. This assessment refers to a single collection event, long-term harvesting over wide spatial scales will lead to greater impacts, with lower resistance and longer recovery times. Intense harvesting of littorinids, coupled with removal of limpets would be likely to result in enhance growth of ephemeral algae based on Atalah & Crowe (2010).

Removal of non-target species	Low Q: Low A: NR C: NR	Low Q: High A: Low C: Medium	High Q: Low A: Low C: Low

Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by *Osmundea pinnatifida* and other algae and invertebrates. The loss of the biological assemblage due to incidental removal as by-catch would therefore alter the character of the habitat and result in the loss of species richness. The ecological services such as primary and secondary production and the habitat provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species resulting in bare rock would alter the character of the biotope, species richness and ecosystem function. Resistance is therefore assessed as ‘Low’ and recovery as ‘High’ (where fronds are removed but bases remain), so that sensitivity is assessed as 'Low'.

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