Peacocks tail (*Padina pavonica*)

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

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

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Padina pavonica
Photographer: Michael Puleston
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See online review for distribution map

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

Researched by	Carmel Roche & Dr Heidi Tillin	**Refereed by**	Admin
Authority	(Linnaeus) Thivy, 1960		
Other common names	-	**Synonyms**	-

Summary

Description

The frond is thin and leafy, flattish and entire when young, but often concave or almost funnel-shaped in mature specimens, with a laciniate or irregularly lobed margin. The fronds grow up to 10 cm in diameter. The inner (or upper) surface is covered with a thin coating of slime, and the outer (or lower) surface is banded with zones of light brown, dark brown and olive green. Small, fine hairs form concentric lines, 3-5 mm apart, from the outer margin continuing down the outer (coloured) surface of the fronds. Specimens of *Padina pavonica* are morphologically distinct and confusion with other species is unlikely.

Recorded distribution in Britain and Ireland

Recorded along the south coast of England including the Isle of Wight, Pembroke and south coast of Ireland. *Padina pavonica* reaches its northern limits in the British Isles. Its northern recorded limit was Ayr in Scotland in the 19th century (Price *et al.* 1979).

Global distribution

Also reported in the North-east Atlantic European coast, South Atlantic, Indian and Pacific Oceans, and the Mediterranean.

Habitat

Padina pavonica is found in pools on rocky shores consisting of soft substrata and occasionally in the shallow infralittoral. These shore platforms are usually backed by rapidly receding sandstone and mud-stone cliffs. *Padina pavonica* is often found near clay, silt or sandy sediments (Herbert *et al*., 2016).

Depth range

Intertidal in UK

Identifying features

- Concave or almost funnel-shaped frond.
- Frond thin with irregular lobed margin.
- The upper surface has a thin layer of slime.
- Lower surface banded with zones of brown and green.
- Concentric lines of small fine hairs on the lower surface.

Additional information

Padina is one of only two genera of calcified brown algae. *Padina pavonica* is the type species reported from the North-east Atlantic European coast, South Atlantic, Indian and Pacific Oceans, the Mediterranean, and reaches its northern geographical limits in the British Isles. This species is recorded as *Padina parvonia* in some texts, and may also be referred to as turkey-feather algae.

Listed by

UKBAP SPI^{e} SPI^{w} FOCI

Further information sources

Search on:

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Biology review

Taxonomy

Phylum	Ochrophyta	Brown and yellow-green seaweeds
Class	Phaeophyceae	
Order	Dictyotales	
Family	Dictyotaceae	
Genus	Padina	
Authority	(Linnaeus) Thivy, 1960	
Recent Synonyms	-	

Biology

Typical abundance	Moderate density
Male size range	Up to 10 cm
Male size at maturity	Up to 10 cm
Female size range	Up to 10 cm
Female size at maturity	Up to 10 cm
Growth form	Erect, Funnel shaped
Growth rate	No information
Body flexibility	Low (10-45 degrees)
Mobility	Sessile
Characteristic feeding method	Autotroph
Diet/food source	Autotroph
Typically feeds on	Photautotroph
Sociability	Not relevant
Environmental position	Epifloral, Epilithic
Dependency	None.
Supports	Independent
Is the species harmful?	No

Biology information

Padina pavonica has a 'haplodiplontic isomorphic life cycle', like many other algae. This means that its life cycle includes sexual reproduction via male and female plants (known as gametophytes) that produce gametes, and spore producing asexual stages (known as tetrasporophytes).

Habitat preferences

Physiographic preferences	Enclosed coast / Embayment, Open coast
Biological zone preferences	Lower littoral fringe, Mid eulittoral, Sublittoral
Substratum / habitat preferences	Bedrock, Rockpools
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Sheltered, Very sheltered

Salinity preferences	Full (30-40 psu)
Depth range	Intertidal in UK
Other preferences	Mostly found in rock pools between Mean High Water Neaps (MHWN) and Extreme Low Water Springs (ELWS).
Migration Pattern	

Habitat Information

No text entered

Life history

Adult characteristics

Reproductive type	Asexual, Sexual
Reproductive frequency	Annual protracted
Fecundity (number of eggs)	1,000-10,000
Generation time	See additional information
Age at maturity	Fronds mature and dieback within a year, no information was found on longevity of rhizoid mat.
Season	Tetraspores produced from early summer to winter
Life span	Insufficient information

Larval characteristics

Larval/propagule type	Not relevant
Larval/juvenile development	Spores (sexual / asexual)
Duration of larval stage	Not relevant
Larval dispersal potential	No information
Larval settlement period	

Life history information

Padina pavonica has a 'haplodiplontic isomorphic life cycle', like many other algae. This means that its life cycle includes sexual reproduction via male and female plants (known as gametophytes) that produce gametes, and spore producing asexual stages (known as tetrasporophytes). The fronds undergo annual dieback and regrowth from rhizoids.populations in southern England produce tetraspores from early summer into the winter months (Herbert *et al*., 2016). Fronds mature at 20mm, a length that can be reached in about 20 days. The tetraspores are borne in concentric rings of a milimetre width, with all tetraspores in a ring at the same stage of development. Fronds of 50mm may have produced 6-12 generations of tetraspores in sporangial rings over a single annual reproductive period (Herbert et al., 2016). A single frond may produce between 2,500- 7,500 spores over the reproductive period (Herbert *et al*., 2016).

Sensitivity review

Resilience and recovery rates

Padina pavonica is common or abundant at ten sites along the south coast (Herbert *et al.*, 2016). Its northern recorded limit was Ayr in Scotland in the 19th century (Price *et al.*, 1979). Occasionally *Padina pavonica* is recorded outside the core sites but it is not clear whether these records are due to long-range dispersal by propagules, regeneration following a period of dormancy or infrequent recording of populations (Herbert *et al.*, 2016).

Where *Padina pavonica* is impacted by pressures, recovery will require either regrowth of fronds, regrowth from the surviving crustose holdfast or recolonization by propagules. Like other algae. *Padina pavonica* has a complex 'haplodiplontic isomorphic life cycle' (Herbert *et al.*, 2016). This means that the life cycle includes sexual reproduction via male and female plants knows as gametophytes that produce gametes, and spore producing asexual stages (tetraspoprophytes). The gametophytes and tetrasporophytes are morphologically similar. The alternation between life histories is not obligate and the proportion of sexual plants and asexual plants may vary. Throughout its range, gametophyte plants have been rarely reported and populations in the south of England produce asexual tetraspores in the summer (Herbert *et al.*, 2016). In habitats where conditions are unfavourable e.g. high levels of scour, asexual reproduction may maintain populations by retaining genotypes that have adapted to tolerate the prevailing habitat conditions.

Vegetative growth of the rhizoidal mat may be important in maintaining populations of *Padina pavonica* (Herbert *et al.*, 2016). In many species with life stages that include rhizoidal mats or crustose holdfasts and fronds, the tolerances of the basal mat or holdfast to pressures such as temperature changes is often greater that the tolerance of the fronds. This allows the plant to persist in areas exposed to pressures. Regrowth of *Padina pavonica* from vegetative rhizoids was observed following removal of adult plants by scouring (Herbert *et al.*, 2016). At some sites in the UK, *Padina pavonica* has persisted for at least 200 years (Price *et al.*, 1979; Herbert *et al.*, 2016,).

The degree of reproductive connectivity between populations is unknown (Herbert *et al.*, 2016). The low profile of *Padina pavonica* is likely to limit spore dispersal, and it is most probable that the relatively heavy tetraspores sink to the bottom of the rock pools where the parents occur (Herbert *et al.*, 2016). Yet although spore dispersal is thought to be limited, model algal spores are sensitive to strong, short-duration, turbulent transport events, and the spread or invasion rate of macroalgae could potentially be 10–100 kilometres per year (Herbert *et al.* 2016). On the Portuguese coast, an 187 km range extension of Padina pavonica has occurred since the 1950–1960s that has been attributed to recent warming (Lima *et al.*, 2007, cited by Herbert *et al.*, 2016). Dislodged and drifting fronds that bear spores may also support dispersal and colonization of suitable shores that are isolated from other populations. Recolonization may be slow and in five sites in the UK where *Padina pavonica* was previously recorded the species has been extinct since 1868 (Herbert *et al.*, 2016).

Resilience assessment. Where resistance is 'High' resilience is assessed as **'High'** as there is no impact to recover from. Where resistance is 'Medium' or 'Low' with the removal of only fronds and not the rhizoidal mat then recovery will occur via regrowth and resilience is assessed as **'High'** (within 2 years). Where some of the rhizoids are removed (resistance is 'Medium' or 'Low') lateral expansion of rhizoidal mats and settlement by tetraspores will support repopulation, however, as growth may be slow and successful settlement and survival may be episodic, resilience is assessed as **'Medium' (2-10 years).** Recovery where turf and holdfasts are removed (resistance is 'None') over an extended area may be protracted and rely on chance events such as the arrival of drifting fronds with spores. In such instances, resilience would be assessed as **'Very low'.**

Note. 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)	Medium Q: High A: Low C: NR	High Q: Medium A: Medium C: Medium	Low Q: High A: Low C: Low

Intertidal species are exposed to high and low air temperatures during periods of emersion and 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).

Padina pavonica is found in the North-East Atlantic European coast, South Atlantic, Indian and Pacific Oceans, the Mediterranean, and reaches its northern geographical limit in the British Isles. Over its range it experiences warmer air and sea temperatures than in the UK. Its range suggests that it is likely to be tolerant of warmer temperatures, but it should be noted that local populations are likely to have adapted to local temperature regimes and assessments based on the range should be interpreted with caution. The long-term (300 year) population records of *Padina pavonica*, from southern England, indicate population survival throughout periods of temperature variation.

Warmer temperatures have been shown to accelerate growth and spore production. In the spring of 2014, warmer than usual temperatures (mean 11.52°C, anomaly 1.62°C) meant that fronds of *Padina pavonica* appeared on shores in the southern UK 14-30 days earlier than usual (Herbert *et al*., 2016). Warmer spring temperatures can accelerate spore production (Herbert *et al*., 2016). On the Portuguese coast, a 187 km range extension of *Padina pavonica* since the 1950–1960s has been attributed to recent warming (Lima *et al*., 2007).

The rhizoid mat of *Padina pavonica* may have a greater tolerance for acute increases in temperature than the fronds, although no evidence was found to support this.

Sensitivity assessment. Based on distribution and growth and spore production observations made by Herbert *et al.* (2016), *Padina pavonica* is not considered sensitive to a chronic increase in temperature at the pressure benchmark. An acute increase in temperature at the pressure benchmark may exceed physiological tolerances if this coincides with high summer temperatures leading to possible bleaching and frond die-back, as has been observed for other brown algae. However, the rock pool habitat may provide some protection and for most of the year an acute increase at the pressure benchmark may be tolerated by at least the rhizoidal mat if not the fronds. Therefore, resistance is assessed as **'Medium'** as a precaution. Hence, resilience is assessed as **'High'** and sensitivity as **'Low'.**

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

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).

Padina pavonica is at the northern most limit of its geographical range in the UK suggesting that a long-term, reduction in temperature may reduce habitat suitability for this species. Herbert *et al.* (2016) assessed a 300-year time series of *Padina pavonica* populations in southern England. At some sites populations have persisted for at least 200 years and the UK population has withstood the conditions of the Little Ice Age at the end of the 17th century and particularly cold winters such as 1947, 1963 and 2010-2011 (Price *et al.*, 1979; Herbert *et al.*, 2016). The survival is attributed to the tolerance of the rhizoidal stage that is tolerant of low temperatures although growth and spore production may be inhibited during cooler periods (Herbert *et al.*, 2016). In spring 2013, when temperatures were cooler than usual (mean 9.26°C temperature anomaly -0.63°C) the appearance of *Padina pavonica* fronds was delayed at all sites in southern England (Herbert *et al.*, 2016).

Sensitivity assessment. *Padina pavonica* is at the northern limit of its range in the UK and lower temperatures that are less than the chronic pressure benchmark have been shown to inhibit the appearance of fronds and effect spore production (Herbert *et al.*, 2016). *Padina pavonica* is, therefore, considered to have **'Medium'** resistance to decreases in temperature based on a reduction in frond growth and spore production and to have 'High' resilience (where rhizoids survive) following reestablishment of typical temperatures. Therefore, sensitivity is assessed as **'Low'**.

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

No evidence was found to assess the salinity tolerances of *Padina pavonica*. As it occurs in intertidal coastal habitats that experience full salinity (Price *et al.*, 1979), the assessed change at the pressure benchmark is an increase in salinity to hypersaline (>40 ppt). Like all species found in the intertidal, *Padina pavonica* will naturally experience fluctuations in salinity where evaporation on warm days increases salinity in pools and inputs of rainwater expose individuals to freshwater. Species found in the intertidal typically have some form of physiological adaptations to withstand fluctuations in salinity. Typically the upper shore distribution of species in the intertidal is determined by physiological tolerances to emersion, salinity and temperature (Barnes & Hughes, 1992). Species that occur lower on the shore are exposed to salinity variations for shorter times (due to tidal immersion) than those that occur on the upper shore levels and tend to be less tolerant of salinity changes.

Sensitivity assessment. Although some increases in salinity may be tolerated by *Padina pavonica*, the natural variation, (rather than the pressure benchmark) is generally short-term and mitigated during tidal inundation. Based on the distribution of *Padina pavonica* on the mid to lower shore, this species is considered to be sensitive to a persistent increase in salinity to >40 ppt (for one year; see benchmark). Therefore, resistance is assessed as **'Low'** and it is possible that the rhizoidal mat may be lost. Recovery is assessed as **'Medium'** (following restoration of usual salinity). Sensitivity is, therefore, assessed as **'Medium'.** However, confidence in this assessment is 'Low'.

Salinity decrease (local)	None Q: Low A: NR C: NR	Very Low Q: Medium A: Medium C: Medium	High Q: Low A: Low C: Low

No evidence was found to assess the salinity tolerances of *Padina pavonica*. As this species occurs in the UK in intertidal coastal habitats that experience full salinity (Herbert *et al.*, 2016), 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) for one year.

High rainfall will reduce salinity on rock surfaces or pools 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.

Sensitivity assessment. As *Padina pavonica* is restricted to full salinity habitats it is considered to be sensitive to a long-term decrease in salinity at the pressure benchmark. Resistance is, therefore, assessed as **'None'** and recovery as **'Very low'** . Sensitivity is, therefore, assessed as **'High'**.

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 *Padina pavonica* to changes in water flow at the pressure benchmark. *Padina pavonica* grows on sheltered and wave exposed shores (Herbert *et al.*, 2016) suggesting that it can tolerate a range of water flows. The rhizoid mat of *Padina pavonica* is securely attached and with its low profile is subject to less drag than the upright fronds. Storm events remove fronds, indicating the vulnerability of these on exposed shores to short events of increased water movement. Changes in water flow during storms, however, is likely to exceed the pressure benchmark. Decreased water flow may result in less frond damage so that spore production is enhanced and may also result in more settlement on shores if spores are not removed by water action.

Sensitivity assessment. *Padina pavonica* 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' at the benchmark level. No direct evidence was found to assess this pressure at the benchmark and confidence is low.

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

Emersion is a key factor structuring the distribution of intertidal species (Barnes & Hughes, 1992). *Padina pavonica* is found in the mid-lower shore (Herbert et al., 2016) and shallow subtidal. Increased emergence may result in greater desiccation and result in habitats at the upper limit of the species intertidal range becoming unsuitable for *Padina pavonica*, resulting in a shift in species distribution on the shore.

A decrease in emergence would mean that shallow rockpools would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rockpool may become slightly deeper. Decreased emergence may result in intertidal habitats that were formerly unsuitable increasing in quality, however, over a course of a year *Padina pavonica* is unlikely to become established in great densities in newly suitable areas. Individuals in the shallow subtidal may experience greater grazing pressure or a reduction of light penetration that reduces habitat suitability; light levels are a key factor influencing growth and the penetration of *Padina pavonica* in the shallow subtidal in the Mediterranean is likely due to the greater irradiance in that region (Herbert *et al*., 2016).

Sensitivity assessment. Changes in emergence may result in habitats at the upper and lower parts of the intertidal subtidal range becoming unsuitable for *Padina pavonica* with some losses or gains of habitat. Resistance to increased emergence is assessed as 'Low' as *Padina pavonica* occurs on the mid to lower shore. The basal crusts may allow individuals to persist in conditions that are unfavourable to frond development until the emergence regime is re-established. Recovery is assessed as 'High' (assuming that rhizoids survive) and sensitivity is therefore assessed as 'Medium', so that sensitivity is assessed as 'Low'.

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

Padina pavonica is recorded at locations of varying wave exposure, ranging from sheltered to exposed (Herbert *et al*., 2016). The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch waves would be predicted to be higher. Storm events remove fronds (Herbert *et al*., 2016), indicating the vulnerability of plants on exposed shores to short-term events of increased wave action. Changes in wave height during storms, however, are likely to exceed the pressure benchmark.

Sensitivity assessment. As *Padina pavonica* occurs across a range of exposures, this was considered to indicate, by proxy, that populations in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark. Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that this species is assessed as '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. Campanella *et al.* (2001) and Schintu *et al.* (2010) both highlighted the suitability of *Padina pavonica* to monitor metal pollution but further studies were needed to clarify accumulation patterns.

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.**

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**.

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 the production of oxygen during periods of photosynthesis. Lack of oxygen may impair both respiration and photosynthesis (see review by Vidaver, 1972). *Padina pavonica* 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.

Sensitivity assessment. No direct evidence for the effects of hypoxia on *Padina pavonica* was found. As it will only be exposed to this pressure when submerged and respiration will occur in air, resistance was assessed as **'High'** and resilience as **'High'** (no effect to recover from), resulting in an assessment of '**Not sensitive**'.

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

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).

Padina pavonica is not associated with increased abundance in response to eutrophication but it may adapt to local increases in nutrient levels (Price *et al.*, 1979). In experiments on *Padina pavonica* from the Mediterranean, increased nutrient levels enhanced growth (Celis-Plá *et al.*, 2015). Populations of *Padina pavonica* have been documented on shores in southern England since the late 17th Century and have persisted through periods when anthropogenic inputs of nutrients were potentially both higher and lower than today.

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'.

	Resistance	Resilience	Sensitivity
Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Padina pavonica occurs on shores where there are some sediments, and habitats where it occurs may be subject to periodic sedimentation. The persistence of populations on such shores suggest that individuals would not be affected by the settlement of fine particles of organic matter in pools or on shores. On most shores organic matter is likely to be removed rapidly by water movements or consumed by deposit feeders limiting exposure further.

Although adults are likely to be unaffected, low levels of fine organic matter may inhibit survival and settlement of early life stages. Irving *et al.* (2009) found that survival of *Cystoseira barbata* germlings was negatively impacted (approximately 83% mortality) when exposed to thin layers of sediments (approximately 8.5 g per petri dish) while Moss *et al.* (1973) found that growth of zygotes of *Himanthalia elongata* were inhibited by a layer of silt 1-2 mm thick and that attachment on silt was insecure.

Sensitivity assessment. Based on resistance to sedimentation and exposure to wave action, the resistance of adult *Padina pavonic*a populations is assessed as **'High'** and resilience as **'High'** (by default). Therefore, they are assessed as **'Not sensitive'** to this pressure at the benchmark.

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.

	Resistance	Resilience	Sensitivity
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 rock habitat; sediments would be unsuitable for *Padina pavonica*. 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 *Padina pavonica* populations.

Sensitivity assessment. Based on the loss of suitable habitat, *Padina pavonica* resistance is assessed as **'None'**, resilience is assessed as **'Very low'**, as the change at the pressure benchmark is permanent. *Padina pavonica* 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

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

Padina pavonica occurs 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: Low A: NR C: NR	High Q: Medium A: Medium C: Medium	Low Q: Low A: Low C: Low

Padina pavonica occurs on the rock surface and, therefore, have no shelter from abrasion at the surface. No direct evidence was found to assess abrasion impacts on this species. Abrasion can remove the frond of 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.

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 *Padina pavonica* is assessed as **'Medium'** (<25% of population damaged or removed) as some damage to individuals is likely and fronds may be removed although the bases may remain. Recovery is probably **'High'** through regrowth of fronds from rhizoids, 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 rhizoid mat.

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

Padina pavonica occurs on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only (see above) is, therefore, considered to equally represent sensitivity to this pressure.

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

In general, increased suspended particles reduce light penetration and increase scour and deposition, which may adversely affect algae, and interfere with settling spores and recruitment if the factor is coincident with their major reproductive period. Siltation, which may be associated with increased suspended solids and the subsequent deposition of these is assessed separately (see siltation pressures).

Where it occurs intertidally, as it does in the UK, *Padina pavonica* will only be exposed to this pressure when submerged during the tidal cycle, exposure to this pressure is, therefore, limited. *Padina pavonica* occurs on soft substratum shores and is often found adjacent to areas of clays, silts or sands (Herbert et al., 2016). The presence of sediments is likely to lead to periods when water movement and wave action results in high levels of suspended sediment. The persistence of Pa*dina pavonica* on such shores and its survival of smothering events (see siltation pressures below), indicate that it has some tolerance for high levels of suspended solids and scour. The calcified fronds and rhizoids of *Padina pavonica* are likely to be resistant of sediment scour and regeneration will not be dependent on settlement. A reduction in suspended sediment will reduce the level of scour and increase light penetration of the water column enhancing growth.

Sensitivity assessment. The exposure of *Padina pavonica* to suspended sediments in the water column will be limited to immersion periods. Wave action and water flows will re-suspend and remove solids, reducing accumulation. *Padina pavonica* is considered to be 'Not sensitive' to a reduction in suspended solids. An increase in suspended solids may lead to some sub-lethal abrasion of fronds and may reduce growth of *Padina pavonica* that occur in deeper rock pools due to a reduction in light penetration. Resistance is 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 rotundus* or *Furcellaria lumbricalis*.

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

Padina pavonica occurs on soft substratum shores and is often found adjacent to areas of clays, silts or sands (Herbert *et al.*, 2016). Sediment movement by water actions means that *Padina pavonica* is likely to experience siltation and scouring. Its persistence on such shores, indicate that it has some tolerance of this pressure. At Bembridge in the Isle of Wight (southern England), an exposed ledge where *Padina pavonica* is found in shallow rock pools occurs below a sandy beach, the movement of sand leads to frequent smothering of rock pools to depths of 5-25 cm for varying duration and extent (Herbert *et al.* 2016). Sand movements at this site, following summer storms affected clump abundance, smothering and frond-size frequency of *Padina pavonica*, the rhizoid mat is more resistant to scouring and smothering than the fronds and the plants recovered via regrowth from rhizoids. In Compton Bay in the Isle of Wight, *Padina pavonica* abundance changed from 'common' to 'rare' following scouring of mid-shore pools due to sand scouring caused by winter storms (Herbert *et al.*, 2016).

The species' resilience to periods of sand-smothering and abrasion may have facilitated survival on dynamic shores consisting of softer substrata where other, potentially competitive, algal species would fail (Herbert *et al.* 2016).

Sensitivity assessment. *Padina pavonica* is adapted to periodic siltation and scouring. *Padina pavonica* resistance is assessed as **'Medium'** and resilience as **'High'**. Therefore, sensitivity is assessed as **'Low'** at the benchmark of up to 5 cm added in a single discrete event.

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

Sediment movement by water actions means that *Padina pavonica* is likely to experience siltation and scouring. Despite complete sand-smothering in 2012, large clumps of fronds appeared in both 2013 and 2014 (Herbert *et al*., 2016). Recovery of the exposed population from sand-smothering may have been due to the survival of perennating rhizoids and/or spores within the sediment or clay substratum (Herbert *et al*., 2016). However, a longer period of sand-smothering or complete erosion of the substratum surface may negatively affect survival of *Padina pavonica* on a shore(Herbert *et al*., 2016).

Sensitivity assessment. At the pressure benchmark, all the fronds are likely to be damaged and lost. High levels of sediment deposition and scour may also remove some rhizoids hindering recovery. *Padina pavonica* resistance is assessed as **'Low'** and resilience as **'Medium'**. Therefore, sensitvity is assessed as **'Medium'**.

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

Not assessed

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

No evidence

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

Padina pavonica has no hearing perception and this pressure is considered 'Not relevant'.

Introduction of light or shading	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Separating sensitivity to temperature and solar radiation is particularly difficult as they often co-vary. Light irradiance is a major factor influencing macroalgal shore height occupation. Considering the species higher abundance in southern latitudes and greater depth penetration in the Mediterranean, light levels may be particularly significant for growth. Light levels are more important to early growth of *Padina pavonica* than water temperature. It is, therefore, possible that population decline in the late nineteenth century was the result of a combination of stressors including lower irradiance due to longer periods of cloud cover (Herbert *et al*. 2016). The introduction of light could therefore be considered as beneficial for *Padina pavonica*.

Sensitivity assessment. As *Padina pavonica* colonize a broad range of light environments from intertidal to deeper sub tidal habitats it is considered to have '**High'** resistance and, by default, **'High'** resilience and, therefore, is **'Not sensitive'** to this pressure.

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

Barriers that reduce the degree of tidal excursion may alter the supply of propagules to suitable habitats from source populations. Conversely, the presence of barriers may enhance local population supply by preventing the loss of spores from enclosed habitats. The low profile of *Padina pavonica* is considered likely to limit spore dispersal, and it is most probable that the relatively heavy tetraspores sink to the bottom of parent rock pools. The degree of connectivity between populations is unclear (Herbert *et al*., 2016) but it is likely that populations persist through vegetative growth and local recruitment close to adult plants. At the pressure benchmark, barriers are considered unlikely to lead to direct impacts on populations of *Padina pavonica*. As propagule supply is not considered within the pressure benchmark this pressure is assessed as 'Not relevant'.

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 interaction with bottom towed fishing gears and moorings are 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	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 suggest that *Padina pavonica* was subject to translocation or genetic modification.

Introduction or spread of invasive non-indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

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 *Padina pavonica*. *Padina pavonica* often occurs on soft rock substrata and in areas where sediment movement may lead to repeated smothering events (Herbert *et al*., 2016). These habitat characteristics may limit the INIS species that can become established.

Algal species that 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). The red seaweeds *Heterosiphonia japonica* and *Neosiphonia harveyi* may also co-occur on shores but again no impacts have been reported. The red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain.

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 *Crassostrea gigas*, as this reef forming species can alter habitat structure. In the Wadden Sea and the North Sea, *Crassostrea gigas* overgrows mussel beds in the intertidal zone (Diederich, 2005, 2006; Kochmann *et al.*, 2008). However, in softer substratum, it may be removed by water movements and be unable to establish.

Sensitivity assessment. No evidence was found to assess the impact of INIS on *Padina pavonica* .

Introduction of microbial pathogens	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.

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

Seaweeds have been collected from the middle of the 16th century for the iodine industry. Modern day industrial uses for seaweed are extensive and include fertilizer, animal feed, alginate extracts (Phillipi *et a*l., 2014), water treatment, and human food and health supplements (Bixler & Porse, 2010). Commercial harvesting can remove seaweed canopies resulting in effects on the wider ecosystem (Stagnol *et al.*, 2013). Due to the intolerance of macroalgae communities to human exploitation, the European Union put in place a framework to regulate the exploitation of algae establishing an organic label that implies that 'harvest shall not cause any impact on ecosystems' (no. 710/2009 and 834/2007).

Padina pavonica is used in cosmetic products and has also been found to contain anti-fungal properties (Wang *et al.*, 2015). The plants are cultivated in the Mediterranean for these properties. But no evidence was found to suggest that this species is subject to commercial harvesting in the UK. In the 19th century, collecting algae to create herbarium records was a popular hobby and over-collecting of *Padina pavonica* may have occurred on some shores leading to local extinctions (Herbert *et al.*, 2016).

Sensitivity assessment. *Padina pavonica* is attached and a single event of targeted harvesting could therefore efficiently remove individuals and resistance is assessed as **'Low'.** Resilience is assessed as **'High'** as the rhizoid mat is assumed to be unaffected and fronds will regrow from this. Hence, 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.

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

The rhizoid mat is unlikely to be removed as a result of harvesting or collecting of another intertidal species. However, the fronds could be accidentally removed as by-catch when other algal species were being targeted if harvesters were not being selective.

Sensitivity assessment. The resistance of the fronds to incidental removal is **'Low'** due to the easy accessibility of the biotopes location and the inability of these species to evade collection. The rhizoid mat is unlikely to be removed and resilience is assessed as **'High'**, and sensitivity as **'Low'.**

Importance review

Policy/legislation

UK Biodiversity Action Plan Priority	☑
Species of principal importance (England)	☑
Species of principal importance (Wales)	☑
Features of Conservation Importance (England & Wales)	☑

Status

National (GB) importance	Nationally scarce	**Global red list (IUCN) category**	-

Non-native

Native	Native		
Origin	-	**Date Arrived**	-

Importance information

-none-

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