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

Semibalanus balanoides and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles

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

Dr Heidi Tillin

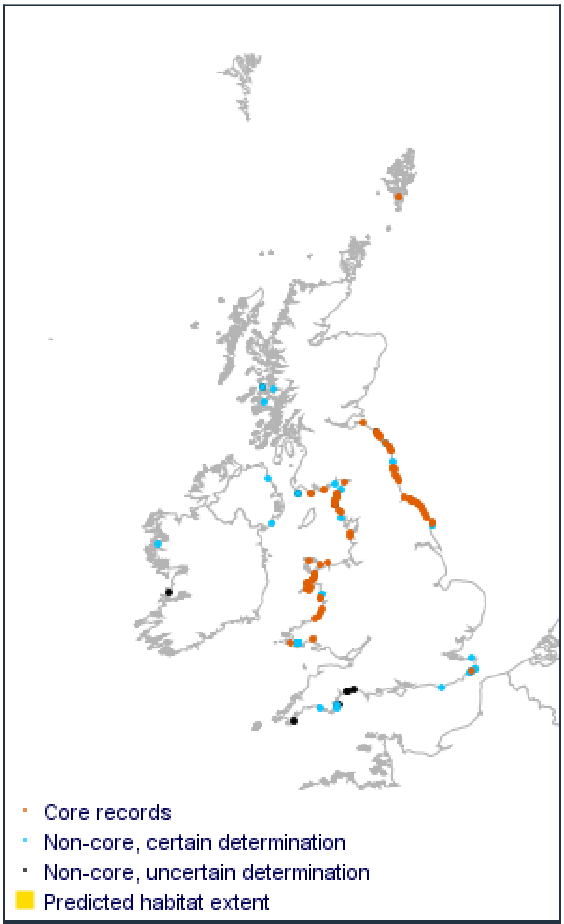
2015-07-17

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

This review can be cited as:
Tillin, H.M. 2015. [Semibalanus balanoides] and [Littorina] spp. on exposed to moderately exposed eulittoral boulders and cobbles. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.1026.1

(page left blank)

Semibalanus balanoides **on exposed to moderately exposed or vertical sheltered eulittoral rock**
Photographer: Paul Brazier
Copyright: Joint Nature Conservation Committee (JNCC)



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

Researched by Dr Heidi Tillin **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A1.1133	*Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles
JNCC 2015	LR.HLR.MusB.Sem.LitX	*Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles
JNCC 2004	LR.HLR.MusB.Sem.LitX	*Semibalanus balanoides* and *Littorina spp*. on exposed to moderately exposed eulittoral boulders and cobbles
1997 Biotope		

Description

Large patches of boulders, cobbles and pebbles in the eulittoral zone on exposed to moderately exposed shores colonised by the barnacle Semibalanus balanoides and, on larger rocks, the limpet *Patella vulgata*. The winkles *Littorina littorea* and *Littorina saxatilis* and the whelk *Nucella lapillus* are typically found in high numbers on and around cobbles and smaller boulders, while the anemone *Actinia equina* occurs in damp areas between and underneath larger boulders. Between the cobbles and pebbles, the mussel *Mytilus edulis* occasionally occurs, but always at low abundance, as do the crab *Carcinus maenas* and gammarid amphipods. Ephemeral green seaweeds such as *Ulva* (syn. *Enteromorpha*) *intestinalis* may cover cobbles and boulders. The foliose red seaweeds *Chondrus crispus*, *Mastocarpus stellatus* and *Osmundea pinnatifida* as well as the wrack Fucus vesiculosus may also occur in low abundance on cobbles and boulders. The top shells *Gibbula cineraria* and *Gibbula umbilicalis* can, on more sheltered shores, be found among the seaweeds or underneath the boulders. The barnacle *Austrominius* (syn. *Elminius*) *modestus* is present on some shores (JNCC, 2015).

Depth range

Mid shore

Additional information

-

Listed By

- none -

Further information sources

Search on:

G g G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope is characterized by *Semibalanus balanoides*, and abundant winkles, *Littorina littorea* and *Littorina saxatilis* on patches of boulders, cobbles and pebbles on moderately exposed shores. The sensitivity assessments specifically consider these species. The limpet *Patella vulgata* and other common rocky shore species may be found, including small *Mytilus edulis* and the anemone *Actinia equina*. Mobile species may structure the assemblage through grazing e.g. *Patella vulgata*, or through predation, e.g. *Nucella lapillus* and *Carcinus maenas*. These species are common on rocky shores and the presence and mobility of the hard surfaces is considered to outweigh predation and grazing as factors that maintain the character of the biotope. The substratum and its mobility are therefore considered, where relevant, in the sensitivity assessments. Ephemeral green seaweeds such as *Ulva intestinalis* may cover cobbles and boulders. The foliose red seaweeds *Chondrus crispus*, *Mastocarpus stellatus* and *Osmundea pinnatifida* as well as the wrack *Fucus vesiculosus* may also occur in low abundance on cobbles and boulders. The sensitivity of the seaweed species is described generally but as these are not considered key characterizing, structural or functional species within the assemblage they do not form the basis of the sensitivity assessment.

Resilience and recovery rates of habitat

Where individuals are removed from a small area, adult limpets and littorinids may recolonize from surrounding patches of habitat where these are present. The recovery of the attached species *Semibalanus balanoides*, *Mytilus edulis* and the macroalgae will depend on larval recolonization. The barnacles, limpets and littorinids are common, widespread species that spawn annually producing pelagic larvae that can disperse over long distances. It is therefore likely that larval supply to impacted areas will provide high numbers of potential recruits. However, a range of factors, including species interactions, determine the rate of successful recruitment of juveniles to the population. The interplay of these factors means that dominant species may alter over time.

Limpets and littorinids may enhance barnacle settlement by grazing and removing algae (Hawkins, 1983) or by depositing pedal mucus trails that attract barnacle larvae (Holmes *et al*., 2005). Barnacles and small clumps of *Mytilus edulis* may enhance survival of small limpets by moderating environmental stresses but they may also have negative effects on recruitment by occupying space and by limiting access to grazing areas (Lewis & Bowman (1975). Dense coverings of mussels and fucoids, however, inhibit settlement of larvae through competition for space or prevention of settlement (Lewis & Bowman, 1975). Limpets may also crush and displace newly settled individuals (Safriel *et al*., 1994).

Environmental factors will also play a role in determining recovery of the biotope. Water currents, wave action and wind direction and strength influence the dispersal and supply of larvae in the water column. The substratum mobility within this biotope may, however, be the key factor structuring the biotope. Where storms or wave action frequently move boulders and cobbles the scour and abrasion may crush and remove species or may result in them being in an unfavourable position. Barnacles and macroalgae that are present on an overturned boulder would be unable to feed or photosynthesise and would die. Therefore the environment may keep the habitat within an early stage of succession, without well-developed clumps of larger macroalgae, thus keeping the rock surface clear for limpets and barnacles.

Life history and reproduction. *Semibalanus balanoides* brood egg masses over autumn and winter and release the nauplii larvae during spring or early summer, to coincide with phytoplankton blooms on which the larvae feed. Local environmental conditions, including surface roughness (Hills & Thomason, 1998), wind direction (Barnes, 1956), shore height, wave exposure (Bertness *et al*., 1991) and tidal currents (Leonard *et al*., 1998) have been identified, among other factors, as affecting the settlement of *Semibalanus balanoides*. Biological factors such as larval supply, competition for space, the presence of adult barnacles (Prendergast *et al*., 2009) and the presence of species that facilitate or inhibit settlement (Kendall *et al*., 1985, Jenkins *et al*., 1999) also play a role in recruitment. Mortality of juveniles can be high but highly variable, with up to 90 % of *Semibalanus balanoides* dying within ten days, therefore successful recruitment may be episodic (Kendall *et al*., 1985).

Semibalanus balanoides may live up to 4 years in higher areas of the shore (Wethey, 1985). Predation rates are variable (see Petraitis *et al*., 2003) and are influenced by a number of factors including the presence of algae (that shelters predators such as the dog whelk, *Nucella lapillus*, and the shore crab, *Carcinus maenas* and the sizes of clearings (as predation pressure is higher near canopies (Petraitis *et al*., 2003).

Barnacles are often quick to colonize available gaps, although a range of factors, as outlined above, will influence whether there is a successful episode of recruitment in a year to re-populate a shore following impacts. Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. Petraitis & Dudgeon (2005) also found that *Semibalanus balanoides* quickly recruited (present a year after and increasing in density) to experimentally cleared areas within the Gulf of Maine, that had previously been dominated by *Ascophyllum nodosum* However, barnacle densities were fairly low (on average 7.6 % cover) as predation levels in smaller patches were high and heat stress in large areas may have killed a number of individuals (Petraitis *et al*., 2003). Following the creation of a new shore in the Moray Firth, *Semibalanus balanoides* did not recruit in large numbers until 4 years after shore creation (Terry & Sell, 1986).

The eggs and larvae form the main mode of dispersal. *Littorina littorea* is an iteroparous breeder with high fecundity that lives for several (at least 4) years. Breeding can occur throughout the year. The planktonic larval stage is long (up to 6 weeks) and dispersal is likely to be affected by the range of factors outlined for *Semibalanus balanoides.*

In northern England, limpets reached sexual maturity in their second year (Blackmore, 1969) and thereafter reproduce annually. Limpets may change sex during their lifetime, with younger animals being male and older animals tending to be female (Blackmore, 1969). In Robin Hood's Bay, Lewis & Bowman (1975) observed spawning of *Patella vulgata* in the Autumn, with spatfall occurring in winter when desiccation pressures were lower.

Recolonization of *Patella vulgata* on rocky shores is rapid as seen by the appearance of limpet spat 6 months after the Torrey Canyon oil spill reaching peak numbers 4-5 years after the spill. Similarly, following the creation of a new rocky shore in the Moray Firth, *Patella vulgata* was present in quadrats after 3 years (Terry & Sell, 1986). However, although recolonization was rapid following the oil spill, the alteration to the population structure (size and age class) persisted for about 15 years because of the complex cycles of dominance (see below) involving limpets, barnacles and algae (Hawkins & Southward, 1992; Lewis & Bowman, 1975). Hence the establishment of fucoids if *Patella vulgata* and other grazers were absent may lead to the long-term exclusion of this species.

Resilience assessment. No evidence for recovery rates was found specifically for this biotope. The evidence suggests that the size of the footprint of an impact and the magnitude will influence the recovery rates by mediating settlement and post-settlement recruitment. Recovery of the attached characterizing species, *Semibalanus balanoides* and the algal turfs will depend on recolonization by larvae. *Patella vulgata* and the littorinids are mobile, but the ability to relocate depends on the presence of suitable adjacent habitats as a source of colonists.

All the characterizing species and others that are present, such as *Mytilus edulis* produce pelagic larvae. As these are common, widespread species, larval supply from adjacent populations should support recolonization where the impact footprint is small. Where source populations are very distant due to regional impacts or habitat discontinuities, larval supply and recovery could be affected. Changes and recovery trajectories following the removal of key species are unpredictable and interactions between the key species may be positive or negative. The wave exposure and substratum mobility of the shores that this biotope is found on, coupled with grazing may limit initial settlement of macroalgae and reduce the presence of large species and individuals, due to the frequency of disturbance.

Limpets and littorinids are mobile and may re-occupy impacted areas. Barnacles are attracted to settle in the presence of adults of the same species (Prendergast *et al*., 2009); so that the presence of adults will facilitate recovery. The resilience of the biotope is assessed as **'High'** (within 2 years) where resistance is 'High' (no significant impact) or 'Medium' (<25% of characteristic biotope removed). A resistance of medium assumes that either a large proportion of the biotope is unimpacted or that the entire biotope is impacted but only a proportion of the characterizing species are removed, with unimpacted areas or individuals supporting recovery. As recruitment may be episodic and the age structure of the limpet population will require more time to recover, resilience is assessed as **'Medium'** (2-10 years) where resilience is 'None' or 'Low'.

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 recognisable 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: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Intertidal species 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 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 that the animal usually occurs at (Davenport & Davenport, 2005).

The median upper lethal temperature limit in laboratory tests on *Littorina saxatilis* and *Littorina littorea* collected in the summer at Great Cumbrae, Scotland), was approximately 35 ° (Davenport & Davenport, 2005). *Semibalanus balanoides* collected from the same shores had a similarly high thermal tolerance, with summer collected individuals having a median upper lethal limit of approximately 35°C.

In laboratory experiments *Littorina littorea* collected from the Kiel Fjord in Germany and kept in tanks at temperatures 5 °C above the seawater temperatures from the collection area (Kiel fjord, Germany) for 5 months (temperatures in laboratory ranged from 13-23°C) did not die although some decreases in shell strength were observed (Landes & Zimmer, 2012).

As suggested by its presence in upper parts of the shore, *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). Lower temperatures enhance feeding rates in adults (Thompson *et al*., 2004). Juvenile tolerance of warm air temperatures and desiccation may be lower than adults.

Although adults may be able to withstand acute and chronic increases in temperature at the pressure benchmark, increased temperatures may have sub-lethal effects on the population by impacting the success of reproduction phases. The distribution of both the key characterizing species, *Semibalanus balanoides* and *Patella vulgata* are 'northern' with their range extending from Portugal or Northern Spain to the Arctic circle. Populations in the southern part of England are therefore relatively close to the southern edge of their geographic range.

Semibalanus balanoides are found on the mid-shore but are less resistant to desiccation than the 'southern' Chthamalus barnacle species. Long-term time series show that successful recruitment of *Semibalanus balanoides* is correlated to sea temperatures (Mieszkowska, *et al*., 2014) and that due to recent warming its range has been contracting northwards. Temperatures above 10 to 12 °C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10 °C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al*., 2014). Observations of recruitment success in *Semibalanus balanoides* throughout the South West of England, strongly support the hypothesis that an extended period (4-6 weeks) of sea temperatures <10 °C is required to ensure a good supply of larvae (Rognstad *et al*., 2014, Jenkins *et al*., 2000). During periods of high reproductive success, linked to cooler temperatures, the range of barnacles has been observed to increase, with range extensions in the order of 25 km (Wethey *et al*., 2011), and 100 km (Rognstad *et al*., 2014). Increased temperatures are likely to favour chthamalid barnacles rather than *Semibalanus balanoides* (Southward *et al*. 1995). *Chthamalus montagui* and *Chthamalus stellatus* are warm water species, with a northern limit of distribution in Britain so are likely to be tolerant of long-term increases in temperature. Similarly, the limpet *Patella depressa* is a southern species, and is therefore considered more tolerant of increased temperature. Thus, an increase in temperature over longer timescales could lead to a change in the dominant species of barnacle and limpet, particularly in more southern regions.

Long-term time studies in southern England suggest that *Patella vulgata* have become scarcer following warmer summers, while *Patella depressa* increase in abundance (Southward *et al*., 1995). Increased temperatures may alter spawning cues and reproduction success in *Patella* *vulgata* populations. Observations suggest that spawning is initiated in autumn storms with greater wave action when seawater temperatures drop below 12°C (Bowman 1985, Bowman & Lewis, 1986, LeQuesne, 2005). In Northern Portugal warming seas appear to be linked to a shortening of the reproductive period and the lack of multiple spawning events in *Patella vulgata* and other northern species (Ribeiro *et al*., 2009).

Most of the other species within the biotope are eurythermal (e.g. *Nucella lapillus* and *Mytilus edulis*) and are also hardy intertidal species that tolerate long periods of exposure to the air and consequently wide variations in temperature. In addition, most species are distributed to the north of south of the British Isles and unlikely to be adversely affected by long-term temperature changes at the benchmark level. *Corallina officinalis*, however, experienced severe damage during the unusually hot summer of 1983 (Hawkins & Hartnoll, 1985).

Sensitivity assessment. Adult *Semibalanus balanoides* and *Patella vulgata* are considered likely to be able to tolerate an acute or chronic increase in temperature at the pressure benchmark, however, if an acute change in temperature occurred in autumn or winter it could disrupt reproduction in *Semibalanus balanoides* and *Patella vulgata*, while a chronic change could alter reproductive success if it exceeded thermal thresholds for reproduction. The effects would depend on the magnitude, duration and footprint of the activities leading to this pressure. However, barnacle populations are highly connected, with a good larval supply and high dispersal potential (Wethey *et al*., 2011, Rognstad *et al*., 2014). Similarly *Patella vulgata* are common, widespread species and therefore larvae are likely to be supplied by local populations to counteract local reproductive failures. The littorinids breed throughout the year and are not considered sensitive at the pressure benchmark. Resistance of the characterizing species is therefore assessed as 'High' and resilience as 'High' (by default). This biotope is therefore considered to be 'Not sensitive' at the pressure benchmark. Sensitivity to longer-term, broad-scale perturbations such as increased temperatures from climate change would however be greater, based on the extent of impact and the reduction in larval supply.

Temperature decrease (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium 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 that the animal usually occurs at (Davenport & Davenport, 2005).

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). A decrease in temperature at the pressure benchmark is therefore unlikely to negatively affect this species. 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. In experiments *Littorina littorea* were able to tolerate temperatures down to -8 °C for 8 days (Murphy, 1983). In colder conditions an active migration may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less

The limpet *Patella vulgata can* also tolerate long periods of exposure to the air and consequently wide variations in temperature. Adults 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, and stopped only by still more severe weather. However, 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). 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).

The distribution of both the key characterizing species, *Semibalanus balanoides* and *Patella vulgata* are 'northern' with their range extending from Portugal or Northern Spain to the Arctic circle. Over their range they are therefore subject to lower temperatures than in the UK, although distributions should be used cautiously as an indicator of thermal tolerance (Southward *et al*., 1995). The barnacle *Semibalanus balanoides* is primarily a ‘northern’ species with an arctic-boreal distribution. Long-term time series show that recruitment success is correlated to lower sea temperatures (Mieszkowska *et al*., 2014). Due to warming temperatures its range has been contracting northwards. Temperatures above 10 to 12 °C inhibit reproduction (Barnes, 1957, 1963; Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10 °C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al*., 2014).

The associated species *Mytilus edulis* is a eurytopic species found in a wide temperature range and in areas which frequently experience freezing conditions and are vulnerable to ice scour (Seed & Suchanek 1992).

Sensitivity assessment. Based on the wide temperature tolerance range of *Patella vulgata* and *Littornia littorea* and other littornids it is concluded that the acute and chronic decreases in temperature described by the benchmark would have limited effect. Similarly, based on global temperatures and the link between cooler winter temperatures and reproductive success, *Semibalanus balanoides* is also considered to be unaffected at the pressure benchmark. A decrease in temperature will favour *Semibalanus balanoides* over other barnacle species (Southward *et al*., 1995). Other species in the biotope also how low intolerance to decreases in temperate. long-term chronic temperature decreases may reduce growth. Therefore, a benchmark decrease in temperature is likely to result in sub-lethal effects only and this this biotope is considered to have ‘High’ resistance and ‘High resilience (by default) to this pressure and is therefore considered to be ‘Not sensitive’.

Salinity increase (local)	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

The biotope occurs in areas of full salinity although will be subject to some variability because of rainfall in the intertidal. However, there are no reports of the biotope occurring in hypersaline areas such as rockpools where evaporation in the summer causes salinity to increase. In the laboratory, *Semibalanus balanoides* was found to tolerate salinities between 12 and 50 psu (Foster, 1970). Young *Littorina littorea* inhabit rock pools where salinity may increase above 35psu. Thus, key species may therefore be able to tolerate some increase in salinity.

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

Evidence on salinity tolerances was found for the characterizing limpet and barnacle species. *Patella vulgata* can tolerate varying salinities and its distribution extends into the mouths of estuaries surviving in salinities down to about 20psu. However, growth and reproduction may be impaired in reduced salinity. Little *et al.* (1991), for example, observed reduced levels of activity in limpets after heavy rainfall and in the laboratory activity completely stopped at 12psu. The species can endure periods of low salinity and was found to die only when the salinity was reduced to 3-1psu (Fretter & Graham, 1994). In experiments where freshwater was trickled over the shell Arnold (1957) observed limpets withdrawing and clamping the shell onto the substratum. There appears to be an increasing tolerance of low salinities from the lower to the upper limit of distribution of the species on the shore (Fretter & Graham, 1994).

Semibalanus balanoides are tolerant of a wide range of salinity and can survive periodic emersion in freshwater, e.g. from rainfall or freshwater run-off, by closing their opercular valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 (Jenkins *et al*., 2001). In areas of permanently reduce salinity the Australin barnacle *Austrominius* (formerly *Elminius*) *modestus* may be favoured, as this species is more tolerant of lower salinities), although this is balanced against its lower tolerance of wave exposure

Littorina littorea is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are not likely to be highly intolerant of decreases in salinity. Therefore, it appears that the biotope would have low intolerance to a decrease in salinity. On return to normal conditions recovery is likely to be very rapid.

Similarly, most of the associated species (e.g. *Mytilus edulis)* are found in a wide range of salinities and are probably tolerant of variable or reduced salinity. Prolonged reduction in salinity, e.g. from full to reduced, is likely to reduce the species richness of the biotope due to loss of less tolerant red algae and some intolerant invertebrates. However, the dominant species will probably survive and the integrity of the biotope is likely to be little affected. Areas of freshwater runoff in the intertidal promote the growth of ephemeral greens, probably due to their tolerance of low salinities and inhibition of grazing invertebrates.

Sensitivity assessment. Based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses in *Patella vulgata*, *Littorina littorea* and *Semibalanus balanoides* it is considered that the benchmark decrease in salinity (from full to variable) would not result in mortality of the characterizing species in biotopes that were previously fully marine. Resistance is therefore assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

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

The biotope is characteristic of exposed to moderately wave exposed conditions where water movement from wave action will greatly exceed the strength of any possible tidal flow. Evidence is presented for the tolerance of the key characterizing species, *Semibalanus balanoides* and *Patella* *vulgata* to changes in water flow. However, it should be noted that wave action is more significant as an environmental factor than water flow for this biotope.

Growth and reproduction of *Semibalanus balanoides* is influenced by food supply and water velocity (Bertness *et al*., 1991). Laboratory experiments demonstrate that barnacle feeding behaviour alters over different flow rates but that barnacles can feed at a variety of flow speeds (Sanford *et al*., 1994). Flow tank experiments using velocities of 0.03, 0.07 and 0.2 m/s showed that a higher proportion of barnacles fed at higher flow rates (Sanford *et al*., 1994). Feeding was passive, meaning the cirri were held out to the flow to catch particles; although active beating of the cirri to gernerate feeding currents occurs in still water (Crisp & Southward, 1961). Field observations at sites in southern New England (USA) that experience a number of different measured flow speeds, found that *Semibalanus balanoides* from all sites responded quickly to higher flow speeds, with a higher proprtion of individuals feeding when current speeds were higher. Barnacles were present at a range of sites, varying from sheltered sites with lower flow rates (maximum observed flow rates <0.06- 0.1 m/s), a bay site with higher flow rates (maximum observed flows 0.2-0.3 m/s) and open coast sites (maximum observed flows 0.2-0.4 m/s). Recruitment was higher at the site with flow rates of 0.2-0.3 m/s (although this may be influenced by supply) and at higher flow microhabitats within all sites. Both laboratory and field observations indicate that flow is an important factor with effects on feeding, growth and recruitment in *Semibalanus balanoides* (Sanford *et al*., 1994; Leonard *et al*., 1998), however, the results suggest that flow is not a limiting factor determining the overall distribution of barnacles as they can adapt to a variety of flow speeds.

Patella vulgata inhabits a range of tidal conditions and is therefore, likely to tolerate a change in water flow rate. The streamlined profile of limpet shells is of importance in increasing their tolerance of water movement, and this is undoubtedly one factor in determining the different shape of limpets at different exposures. With increasing exposure to wave action the shell develops into a low profile reducing the risk of being swept away. The strong muscular foot and a thin film of mucus between the foot and the rock enables *Patella vulgata* to grip very strongly to the substratum (Fretter & Graham, 1994). The ability of limpets to resist accelerating, as distinct from constant currents, may set a limit to the kind of habitat which they can occupy and limit the size to which they can grow.

Littorina littorea is found in areas with water flow rates from negligible to strong, although populations exposed to different levels of flow may have adapted to local conditions. Increases in water flow rates above 6 knots may cause snails in less protected locations (e.g. not in crevices etc) to be continually displaced into unsuitable habitat so that feeding may become sub-optimal. Thus, populations of *Littorina littorea* are likely to reduce. Shell morphology within littorinids varies according to environmental conditions, in sheltered areas shell apertures are small to inhibit predation where *Carciunus maenas* is more prevalent. In exposed areas the foot surface is larger to allow greater attachment and the shell spire is lower to reduce drag (Raffaelli 1982; Crothers, 1992).

Sensitivity assessment. The biotope is characteristic of exposed to moderately wave exposed conditions where water movement from wave action will greatly exceed the strength of any possible tidal flow. Based on the available evidence the characterizing species *Patella vulgata*, *Littorina littorea* and *Semibalanus balanoides* are able to adapt to high flow rates and the biotope is therefore considered to be 'Not sensitive' to an increase in water flow. A decrease in water flow may have some effects on recruitment and growth, but this is not considered to be lethal at the pressure benchmark and resistance is therefore assessed as 'High' and resilience as 'High' by default, so that the biotope is considered to be 'Not sensitive'. A decrease in water flow, exceeding the pressure benchmark, coupled with a decrease in wave action, may, however, alter the character of the biotope to LR.MLR.MusF.MytFR or LR.MLR.MusF.MytFves, where brown seaweeds were able to proliferate and the edible periwinkle *Littorina littorea* was able to colonize.

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

Emergence regime is a key factor structuring this (and other) intertidal biotopes. Increased emergence may reduce habitat suitability for characterizing species through greater exposure to desiccation and reduced feeding opportunities for the barnacles to feed when immersed. *Semibalanus balanoides* is less tolerant of desiccation stress than *Chthamalus* barnacles species and changes in emergence may therefore lead to species replacement and the development of a *Chthamalus* sp. dominated biotope, more typical of the upper shore may develop. Records suggest that, typically, above this biotope on the shore there may be a *Verrucaria maura* and sparse barnacle zone, or a *Chthamalus* and limpet zone (Connor *et al*., 2004). Increased emergence may therefore eventually lead to replacement of this biotope to one more typical of the upper shore.

Decreased emergence would reduce desiccation stress and allow the attached suspension feeders more feeding time. Predation pressure on mussels and barnacles is likely to increase where these are submerged for longer periods and to prevent colonisation of lower zones. *Semibalanus balanoides* was able to extend its range into lower zones when protected from predation by the dogwhelk, *Nucella lapillus* (Connell, 1961). Competition from large fucoids and red algal turfs can also prevent *Semibalanus balanoides* from extending into lower shore levels (Hawkins, 1983). Below this biotope there may be *Himanthalia elongata* dominated biotopes, or on less exposed shores, a Fucus serratus biotope on boulders (Connor *et al*., 2004). Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement.

The mobile species present within the biotope, including *Nucella lapillus*, *Patella vulgata* and the littorinids would be able to relocate to preferred shore levels.

Sensitivity assessment. Where this biotope occurs on the mid-shore it will be more sensitive to increased emergence, whereas lower shore examples may be more sensitive to decreased emergence, as the changed conditions occur towards the margins of habitat tolerance. As emergence is a key factor structuring the distribution of animals on the shore, resistance to a change in emergence (increase or decrease) is assessed as ‘Low’. Recovery is assessed as ‘Medium’, and sensitivity is therefore assessed as 'Medium'.

Wave exposure 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 this biotope to changes in wave exposure at the pressure benchmark. 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 two wave exposure categories, 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. An increase or decrease in wave action, exceeding the pressure benchmark, may however alter the character of the biotope. Where wave action was significantly reduced a biotope more typical of sheltered shores would be predicted to develop, e.g. LR.MLR.MusF.MytFR or LR.MLR.MusF.MytFves, where brown seaweeds were able to proliferate on the rock surfaces and the edible periwinkle *Littorina littorea* was able to colonize. A decrease in wave exposure may ultimately reduce *Patella vulgata* abundance because the species does not favour thick algal cover that is often present on very sheltered shores. Alternatively an increase in significant wave height, linked to increased exposure, may result in population changes with fewer macroalgae and barnacles present and with the limpet *Patella ulyssiponensis* present, or present in greater numbers, rather than P*atella vulgata* (Thompson, 1980).

Sensitivity assessment. The natural wave exposure range of this biotope is therefore considered to exceed changes at the pressure benchmark and this biotope is considered to have 'High' resistance and 'High' resilience (by default), to this pressure (at the benchmark).

Chemical Pressures

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

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

Contamination at levels greater than the benchmark may impact this biotope. However, Barnacles, may tolerate fairly high level of heavy metals in nature, for example they possess metal detoxification mechanisms and are found in Dulas Bay, Anglesey, where copper reaches concentrations of 24.5 µg/l, due to acid mine waste (Foster *et al*., 1978; Rainbow, 1984). Bryan (1984) suggested that gastropods are also rather tolerant of heavy metals. 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) 100-2000µg/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 100µg/l for one week resulted in progressive brachycardia (slowing of the heart beat) and the death of limpets. Zn at a concentration of 5500µg/l produced the same effect (Marchan *et al*.,1999).

Littorina littorea is tolerant of high TBT levels (Oehlmann *et al*., 1998) and has been found to be well suited for TBT effect monitoring because the species exists in sufficient numbers for sampling even in regions where a relatively high level of contamination exists. It is often present in areas where the very TBT sensitive dogwhelk *Nucella lapillus* has disappeared. Although imposex is rare in *Littorina littorea* strong TBT-toxication may affect a population significantly by reducing reproductive ability (Deutsch & Fioroni, 1996) through the development of intersex. Intersex is defined as a change in the female pallial oviduct towards a male morphological structure (Bauer *et al*., 1995). However, only sexually immature and juvenile individuals of *Littorina littorea* are able to develop intersex. Also, owing to the reproductive strategy of *Littorina littorea*, which reproduces by means of pelagic larvae, populations do not necessarily become extinct as a result of intersex (Casey *et al*., 1998) and so recoverability is good. It may take some time for the toxicant to be eliminated from the system and conditions to return to normal.

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 the diet, and evidence from experimental studies on *Littorina littorea* suggest that the 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) suggests that the species is a reasonable indicator for Ag, Cd, Pb and perhaps As. It is not found to be a reliable indicator for other metals because of some interactions between metals and regulation of some, such as Cu and Zn (Langston & Zhou Mingjiang, 1986). The lethal dose of mercury (as mercury chloride) is between 1 and 10 ppm of seawater (Staines Web page). This stems mainly from its ability to accumulate trace elements and compounds and consequential behavioural changes.

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.

Hydrocarbon contamination, at levels greater than the benchmark, e.g. from spills of fresh crude oil or petroleum products, may cause significant loss of component species in the biotope, through impacts on individual species viability or mortality, and resultant effects on the structure of the community (Suchanek, 1993; Raffaelli & Hawkins, 1999).In areas of moderate oil deposit, up to about 1/2cm thick, on rocks after the *Torrey Canyon* oil spill, limpets had survived unscathed over a month after the event and feeding continued even though a coating of oil smothered their food source of algae and diatoms (Smith, 1968). Limpets can ingest thick oil and pass it through their gut. However, thick layers of oil smothering individuals will interfere with respiration and spoil normal food supplies for *Patella vulgata*. Limpets are unable to remain closed off from the environment for very long, the adductor muscles relax occasionally, lifting the shell very slightly. 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). Thus *Patella vulgata* has higher intolerance to fresh oil which has a high component of volatile hydrocarbons remaining. A significant reduction in the density of juvenile limpets was also observed at all sites known to have been oiled by the *Sea Empress* spill (Moore, 1997). 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.

Littoral barnacles (e.g. *Semibalanus balanoides*) have a high resistance to oil (Holt *et al*., 1995) but may suffer some mortality due to the smothering effects of thick oil (Smith, 1968).

Laboratory studies of the effects of oil and dispersants on several red algae species (Grandy, 1984 cited in Holt *et al*. 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination.

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.

Synthetic compound contamination, at levels greater than the benchmark, is likely to have a variety of effects depending the specific nature of the contaminant and the species group(s) affected. Barnacles have a low resilience to chemicals such as dispersants, dependant on the concentration and type of chemical involved (Holt *et al*., 1995). Hoare & Hiscock (1974) reported that the limpet *Patella vulgata* was excluded from sites within 100-150m of the discharge of acidified, halogenated effluent in Amlwch Bay. Limpets are also extremely intolerant of aromatic solvent based dispersants used in oil spill clean-up. During the clean-up response to the *Torrey Canyon* oil spill nearly all the limpets were killed in areas close to dispersant spraying. Viscous oil will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone or diluted in seawater, would creep in much more readily and be liable to kill the limpet (Smith, 1968). A concentration of 5ppm killed half the limpets tested in 24 hours (Southward & Southward, 1978; Hawkins & Southward, 1992). Acidified seawater affects the motility of *Patella vulgata*. At a pH of 5.5 motility was reduced whilst submerged but individuals recovered when returned to normal seawater. At a pH of 2.5 total inhibition of movement occurred and when returned to normal seawater half had died (Bonner *et al*., 1993). Reduced motility reduces time for foraging and may result in decreased survival of individuals. Acidified seawater can also change the shell composition which will lead to a decrease in its protective nature and hence survival (Bonner *et al*., 1993). Short periods (48 hours) are unlikely to have much effect on a population but long periods (1 year) may cause reduced grazing and an increase in algal growth. However, seawater is unlikely to reach pH 2.5 therefore intolerance to slight changes in pH will be low. Gastropod molluscs are known to be intolerant of endocrine disruption from synthetic chemicals such as tri-butyl tin (Cole *et al*., 1999). However no information on the specific effects of tri-butyl tin on *Patella vulgata* was found. Hoare & Hiscock (1974) reported that in Amlwch Bay *Patella vulgata* was excluded from sites within 100-150m of the discharge of acidified, halogenated effluent.

Red algae are probably intolerant of chemical contamination. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil contamination, although the filamentous forms were the most sensitive. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (Grandy, 1984 cited in Holt *et al*., 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Cole *et al*. (1999) suggested that herbicides, such as simazina and atrazine were very toxic to macrophytes. In addition, Hoare & Hiscock (1974) noted that almost all red algae were excluded from Amlwch Bay, Anglesey by acidified halogenated effluent discharge.

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

No evidence.

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

This pressure is **Not assessed**.

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

An oxygen concentration at the level of the benchmark, 2mg/l, is thought likely to cause adverse effects in marine organisms. In laboratory experiments a reduction in the oxygen tension of seawater from 148mm Hg (air saturated seawater) to 50mm Hg rapidly resulted in reduced heart rate in limpets of the genus *Patella* (Marshall & McQuaid, 1993). Heartbeat rate returned to normal in oxygenated water within two hours. Limpets can 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. However, *Patella vulgata* is an intertidal species, being able to respire in air, and in 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 ioxygen in the air into water or flushing with oxygenated waters.

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).

Littorina littorea have a high tolerance for low oxygen conditions and can easily survive 3-6 days of anoxia (Storey *et al*., 2013). In addition, *Littorina littorea*, like *Patella vulgata*, is an air breather when emersed, so can respire during the tidal cycle.

Sensitivity assessment. The key characterizing species, littorinids, *Patella vulgata* and *Semibalanus balanoides* are considered to be 'Not Sensitive' to de-oxygenation at the pressure benchmark. The experiments cited as evidence (Marshall & McQuaid, 1993; Grenon & Walker, 1981 and Barnes *et al*., 1963) exceed the duration and/or magnitude of the pressure benchmark and do not take into account the environmental mitigation of deoxygenation occurring in this biotope. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (no effect to recover from), resulting in a sensitivity 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

No direct evidence was found to assess this pressure. A slight increase in nutrient levels could be beneficial for barnacles and mussels by promoting the growth of phytoplankton levels and therefore increasing zooplankton levels. Limpets and other grazers would also benefit from increased growth of benthic microalgae. However, Holt *et al*. (1995) predict that smothering of barnacles by ephemeral green algae is a possibility under eutrophic conditions. However, if nutrient loading is excessive this can have a detrimental effect on algal productivity and hence limpet growth.

Littorina littorea occurs on all British and Irish coasts, including lower salinity areas such as estuaries where nutrient loading is likely to be higher than elsewhere. Higher nutrient levels may benefit the algal substrata and food used by the snail. In situations with nutrient enrichment, primary productivity in terms of biofilms and/ or green algae will generally be enhanced, which may supply more food or more nutrient rich food. This can reduce the browsing distances and periods of *Littorina*, reducing times spent searching for food (Diaz *et al*. 2012). After five months of nutrient addition in experimental mesocosms, *Littorina* abundance and biomass had increased compared to controls. Enriched mesocosms experiments were treated with 32 lM inorganic nitrogen (N) and 2 lM inorganic phosphorus (P) above the background levels in the Oslofjord continuously in the period April–September 2008. These nutrient addition levels are similar to concentrations recorded in eutrophic areas locally (Kristiansen & Paasche, 1982; cited in Diaz *et al*. 2012) and globally (Cloern, 2001; cited in Diaz *et al*. 2012).

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

Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and de-oxygenation). The biotopes occurs in tide swept or wave exposed areas (Connor *et al*., 2004) preventing a build up of organic matter, so that the biotope is considered to have a low risk of organic enrichment at the pressure benchmark. Little evidence was found to support this assessment, Cabral-Oliveira *et al*., (2014), found that filter feeders such as *Mytilus* sp. and the barnacle *Chthamalus montagui*, were more abundant at sites closer to a sewage treatment works, as they could utilise the organic matter inputs as food. On the same shores, higher abundances of juvenile *Patella* sp. and lower abundances of adults were found 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. Little empirical evidence was found to support an assessment for *Semibalanus balanoides* and *Patella vulgata* within this biotope. As organic matter particles in suspension or re-suspended could potentially be utilised as a food resource by filter feeders present within the biotope (Cabral-Oliveira *et al*., 2014) with excess likely to be rapidly removed by wave action, overall resistance of the biological assemblage within the biotope is considered to be 'High' and resilience was assessed as 'High', so that this biotope is judged to be 'Not sensitive'. Limpets may be sensitive to even low levels of deposition (see siltation pressure), so that impacts from this pressure will depend on the duration of input and any deposits.

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: High A: High C: High	Very Low Q: High A: Medium C: High	High Q: High A: Medium C: High

This biotope is characterized by the hard rock substratum provided by the boulders and cobbles to which the key characterizing species barnacles, limpets and littorinids and the other associated species can firmly attach. littorinids are found on a variety of shores, including sedimentary so a change in type may not significantly affect this species. A change to a sedimentary substratum would, however, significantly alter the character of the biotope. Changes in substratum type can also lead to indirect effects. For example, Shanks & Wright (1986) observed that limpet mortalities were much higher at sites where the supply of loose cobbles and pebbles were greater, leading to increased abrasion through wave action 'throwing' rocks onto surfaces. The biotope is, therefore, considered to have **No** resistance to this pressure, resilience is **Very low** (the pressure is a permanent change) and sensitivity is assessed as **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 epifauna or epiflora 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: High C: High	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

The key characterizing and associated species within this biotope typically occur on the rock surfaces where they will be exposed to abrasion. Although barnacles, limpets and littorinids are protected by hard shells or plates, 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 is 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 appear 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 reported 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 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/hrs) led to reductions in barnacle cover.

Single step experiments provide a clearer, quantitative indication of sensitivity to direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victora, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamalus 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 *Chthamalus fissus* aggregations 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 the 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* compared with other, local sites with stable substratum (Carlson *et al*., 2006).

Trampling may lead to indirect effects on limpet populations, Bertocci *et al*., (2011) found that the effects of trampling on *Patella* sp. increased the temporal and spatial variability of in abundance. The experimental plots were sited on a wave-sheltered shore dominated by *Ascophyllum nodosum*. On these types of shore, trampling in small patches, that removes macroalgae and turfs, will indirectly enhance habitat suitability for limpets, barnacles and littorinids by creating patches of exposed rock for grazing and/or settlement.

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from the step experiments and the relative robustness of these species, resistance, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force than the trampling examples the assessment is based on).

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 epifauna or epiflora occurring on rock, which is resistant to subsurface penetration. Therefore, 'penetration' is '**Not relevant**'. The assessment for abrasion at the surface only is, therefore, considered to equally represent sensitivity to this pressure'. Please refer to 'abrasion' above.

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

In general, increased suspended particles may enhance food supply (where these are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). Very high levels of silt may clog respiratory and feeding organs of the suspension feeding *Semibalanus balanoides* and clog the gills of *Patella vulgata*. In addition, increased turbidity will decrease light penetration reducing photosynthesis by macroalgae within this biotope. Increased levels of particles may increase scour and deposition in the biotope depending on local hydrodynamic conditions, although changes in substratum are assessed through the physical change (to another seabed type) pressure. Gyory *et al.* (2013) found that increased turbidity triggered the release of larvae by *Semibalanus balanoides*, a response that may allow the larval release to be timed with high levels of phytoplankton and at times where predation on larvae may be lowered due to the concentration of particles. Storm events that stir up sediments are also associated with larval release (Gyory & Pineda, 2011).

A significant decrease in suspended organic particles may reduce food input resulting in reduced growth and fecundity of the suspension feeding barnacles. However, local primary productivity (phytoplankton and diatom films) may be enhanced where suspended sediments decrease, increasing food supply to both characterizing species. Decreased suspended sediment may increase macroalgal competition, enhancing diversity, but is considered unlikely to significantly change the character of the biotope as colonization by larger brown macroalgae is likely to be limited by wave action in this biotope.

Sensitivity assessment. The benchmark for this pressure refers to a change in turbidity of one rank on the Water Framework Directive (WFD) scale. Where changes in suspended sediment supply were linked to decreased wave action and water flow to enhance settlement, limpets would be sensitive to deposition (see siltation pressures). The biotope is considered to be 'Not sensitive' to a decrease in suspended solids. An increase in inorganic suspended sediments may negatively affect the feeding of *Semibalanus balanoides* with some impacts on growth and survival. Resistance is, therefore, assessed as 'Medium' and resilience as 'High' so that sensitivity is assessed as 'Low'. The assessment for increased suspended solids is recorded.

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

More direct evidence to assess this pressure was found for the characterizing species *Patella vulgata* and *Littorina littorea*, than *Semibalanus balanoides*. However, the lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear..

Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition (see also the 'heavy' siltation pressure for further information). Airoldi & Hawkins (2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. Sediments were added as a ‘fine’ rain to achieve deposit thicknesses of approximately 1mm, 2 mm, and 4 mm in controlled experiments and grazing and mortality observed over 8-12 days. Limpets were more sensitive to sediments with a higher faction of fines (67% silt) than coarse (58% sand). Coarse sediments of thicknesses approximately 1, 2 and 4 mm decreased grazing activity by 35, 45 and 50 % respectively. At 1 and 2 mm thicknesses, fine sediments decreased grazing by 40 and 77 %. The addition of approximately 4 mm of fine sediment completely inhibited grazing. Limpets tried to escape the sediment but lost attachment and died after a few days (Airoldi & Hawkins, 2007).

Observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England found that *Patella vulgata* abundances were higher where deposits were absent. The limpets were locally absent in plots with 50-65% sediment cover (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.

Littorina littorea through grazing and bulldozing actions may directly aid the removal of silts and sediments and remove the algal films that may accumulate silts (Bertness, 1984). On a protected New England rocky beach, Bertness (1984) showed how accumulation of sediments, due to the removal of the snail *Littorina littorea* changed the character of the habitat to one more typical of sedimentary habitats, with a decrease in the abundance of organisms characteristic of hard-bottom habitats, such as barnacles and encrusting algae (cited from Airoldi, 2003). Chandrasekara & Frid (1998) specifically tested the siltation tolerance of *Littorina littorea*. Burial to 5cm caused mortality within 24 hours at simulated summer and winter temperatures if the snails could not crawl out of the sediment (Chandrasekara & Frid, 1998). If the sediment is well oxygenated and fluid (as with high water, high silt content) a few snails (1-6 out of 15 in the experiment, depending on temperature, sediment and water content) may be able to move back up through 5 cm of sediment (Chandrasekara & Frid, 1998). Approximately half of the test individuals could not regain the surface from 1cm of burial except in the most favourable conditions (low temperatures, high water, high silt when a majority (10 out of 15) of the test cohort surfaced. Field observations support the findings that *Littorina littorea* are generally unable to survive smothering. Albrecht & Reise (1994) observed a population of *Littorina littorea* in a sandy bay near the Sylt island in the North Sea. They found that the accretion of mud within *Fucus* strands and subsequent covering of *Littorina* by the sediment resulted in them suffocating and a significant reduction in their abundance.

Sensitivity assessment. *Semibalanus balanoides* is found permanently attached to hard substrates and is a suspension feeder. This species, therefore, has no ability to escape from silty sediments which would bury individuals and prevent feeding and respiration. However, no direct evidence for sensitivity to siltation was found. Resistance is assessed as ‘Medium’ as wave action on rocky shores is likely to rapidly mobilise and remove deposits alleviating the effect of smothering. Resilience is assessed as ‘High’ and sensitivity is therefore considered to be ‘Low’.

Even small deposits of sediments are likely to result in local removal of limpets and Littorinids. The level of impact will depend on the magnitude and duration of impact. It should be noted that the level of exposure may be reduced by wave action or water flows so that site-specific vulnerability may be lower where sediments do not accumulate. Resistance to siltation is assessed as ‘Low’ for *Patella vulgata* and *Littorina littorea* based primarily on observations and experiments of Airoldi & Hawkins, (2007) and Chandrasekara & Frid, (1998), who demonstrated negative effects at deposit thicknesses at or far lower than the pressure benchmark. Small patches subject to a single impact may recover rapidly via adult migration. However, based on the prolonged recovery times experienced from more wide-ranging impacts, resilience is assessed as ‘Medium’ (2-10 years) and sensitivity is therefore assessed as ‘Medium’. This more precautionary assessment is presented for the biotope, rather than the lower sensitivity of *Semibalanus balanoides*. Repeated deposition events, coupled with changes in water flow and wave action may lead to the establishment of turf-forming algae that trap sediments, this would significantly alter the character of the biotope.

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

More direct evidence to assess this pressure was found for the characterizing species *Patella vulgata* and *Littorina littorea*, than *Semibalanus balanoides*. However, the lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear.

The evidence for siltation effects on the key characterizing species, *Patella vulgata* and *Littorina littorea* are outlined above for ‘light’ deposition. In summary, experiments by Airoldi & Hawkins (2007) and Chandrasekara & Frid, (1998), supported by field observation, indicate that both species would be unable to escape from sediment deposits of 30cm thickness and would rapidly die.

Sensitivity assessment. 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. *Semibalanus balanoides* is found permanently attached to hard substrates and is a suspension feeder. This species, therefore, has no ability to escape from silty sediments which would bury individuals and prevent feeding and respiration. Even small deposits of sediments are likely to result in local removal and death of limpets and littorinids. Resistance to siltation at the benchmark level is assessed as ‘None’ for *Patella vulgata* and *Littorina littorea* based primarily on the observations and experiments of Airoldi & Hawkins, (2007) and Chandrasekara & Frid (1998), who demonstrated negative effects at deposit thicknesses far lower than the pressure benchmark. Small patches subject to a single impact may recover rapidly via adult migration. However, based on the prolonged recovery times experienced on more wide-ranging impacts, resilience is assessed as ‘Medium’ (2-10 years) and sensitivity is therefore 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

Thompson *et al*., (2004) demonstrated that *Semibalanus balanoides*, kept in aquaria, ingested microplastics within a few days. However, the effects of the microplastics on the health of exposed individuals have not been identified. There is currently no evidence to assess the level of impact and this pressure is 'Not assessed'.

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

No evidence.

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

Not relevant. Wave action on exposed shores is likely to generate high levels of underwater noise. Other sources are not considered likely to result in effects on the biotope.

Introduction of light or shading	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 direct evidence to assess this pressure was found for the key characterizing species *Patella vulgata* and the littorinids. As both species occur on open rock and in crevices and under *Fucus canopies* they are considered tolerant of a range of light conditions. *Semibalanus balanoides* sheltered from the sun grew bigger than unshaded individuals (Hatton, 1938; cited in Wethey, 1984), although the effect may be due to indirect cooling effects rather than shading. Light levels have, however, been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoides*. In general, light inhibits aspects of the breeding cycle. Penis development is inhibited by light (Barnes & Stone, 1972) while Tighe-Ford (1967) showed that constant light inhibited gonad maturation and fertilization. Davenport & Crisp (unpublished data from Menai Bridge, Wales, cited from Davenport *et al*., 2005) found that experimental exposure to either constant darkness, or 6 h light: 18 h dark photoperiods induced autumn breeding in *Semibalanus*. They also confirmed that very low continuous light intensities (little more than starlight) inhibited breeding. Latitudinal variations in the timing of the onset of reproductive phases (egg mass hardening) have been linked to the length of darkness (night) experienced by individuals rather than temperature (Davenport *et al*., 2005). Changes in light levels associated with climate change (increased cloud cover) were considered to have the potential to alter the timing of reproduction (Davenport *et al*., 2005) and to shift the range limits of this species southward. However, it is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

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

No direct evidence was found to assess this pressure. As the larvae of the key characterizing species *Patella vulgata*, *Semibalanus balanoides* and *Littorina littorea* are planktonic and are transported by water movements, barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. However, the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. The associated macroalgae and *Littorina saxatilis* have either limited dispersal or produce crawl away juveniles rather than pelagic larvae (direct development). Barriers and changes in tidal excursion are not considered relevant to these species as dispersal is limited. As the key characterizing species are widely distributed and have larvae capable of long distance transport, 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	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

The characterizing Littorinid species, *Semibalanus balanoides* and *Patella vulgata* and other common rocky shores species within the biotope, with the exception of *Mytilus edulis* which occurs in low abundances, are not subject to translocation or cultivation. Commercial cultivation of Mytilus edulis involves the collection of juvenile mussel 'seed' or spat (newly settled juveniles ca 1-2cm in length) from wild populations, with subsequent transportation around the UK for re-laying in suitable habitats. As the seed is harvested from wild populations from various locations the gene pool will not necessarily be decreased by translocations. Movement of mussel seed has the potential to transport pathogens and non-native species (see sensitivity assessments for *Mytilus edulis* bed biotopes). A review by Svåsand *et al*. (2007) concluded that there was a lack of evidence distinguishing between different *Mytilus edulis* populations to accurately assess the impacts of hybridisation with the congener *Mytilus galloprovincialis* and in particular how the gene flow may be affected by aquaculture. Therefore, it cannot be confirmed whether farming will have an impact on the genetics of this species beyond a potential for increased hybridisation.

Sensitivity assessment. No direct evidence was found regarding the potential for negative impacts of translocated mussel seed on wild *Mytilus edulis* populations. While it is possible that translocation of mussel seed could lead to genetic flow between cultivated beds and local wild populations, there is currently no evidence to assess the impact (Svåsand *et al*., 2007). Hybrids would perform the same ecological functions as *Mytilus edulis* so that any impact relates to genetic integrity of a bed alone. Also, given the uncertainty in identification of the species, habitats or biotopes that are considered to be characterized by *Mytilus edulis* may in fact contain *Mytilus galloprovincialis*, their hybrids or a mosaic of the three. Presently, there is no evidence of impact resulting from genetic modification and translocation on *Mytilus edulis* beds in general or the clumps that characterize this biotope.

Introduction or spread of invasive non-indigenous species	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

This biotope is considered to be most vulnerable to invasive non-indigenous species that can outcompete the characterizing species and associated assemblage for space or those species that will predate on the characterizing species.

In terms of space occupation, the Australasian barnacle, *Austrominius modestus*, the Pacific Oyster, *Magallana gigas* and the tunicates, *Botrylloides diegensis*, *Corella eumyota* may be most likely to occur in this 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). However, Brousseau & Goldberg (2007) found that even at high crab densitites the effects of predation on density of *Semibalanus balanoides* were limited as continued recruitment offset predation.

The Australasian barnacle *Austrominius* (previously *Elminius) modestus* was introduced to British waters on ships during the second world war. However, its overall effect on the dynamics of rocky shores has been small as *Austrominius modestus* has simply replaced some individuals of a group of co-occurring barnacles (Raffaelli & Hawkins, 1999). Although present, monitoring indicates it has not outnumbered native barnacles in the Isle of Cumbrae (Gallagher *et al*., 2015) it may dominate in estuaries where it is more tolerant of lower salinities than *Semibalanus balanoides* (Gomes-Filho, *et al*., 2010).

Dense aggregations of *Magallana gigas* on a former mussel bed showed increased abundance and biomass of *Littorina littorea* in the Wadden Sea (Markert *et al*. 2010). However, Eschweiler and Buschbaum (2011) found that juvenile *Littorina littorea* could carry *Magallana gigas* and *Crepidula fornicata* as epibionts. Body dry weight of snails without oyster overgrowth was twice as high compared to winkles covered with oysters. Also crawling speed of snails with oyster epigrowth was significantly slowed down and about ten times lower than in unfouled periwinkles. Additionally, oyster epibionts caused a strong decrease in reproductive output. In laboratory experiments, egg production of fouled *Littorina littorea* was about 100-fold lower than in affected individuals. Field surveys in different years and habitats demonstrated that up to 10% of individuals occurring on epibenthic bivalve beds and up to 25% of snails living on sand flats may be fouled by *Crassostrea gigas*.

Although the results of studies of feeding preferences for *Sargassum muticum* over native macroalgae vary, *Littorina littorea* does feed on this species so shoreline colonization by this species would mean that food was still available (Withers *et al*. 1975). *Littorina littorea* also grazes on degraded or stressed *Didemnum vexillem* individuals (Valentine *et al*., 2007) and *Codium fragile* ssp. *tomentosoides* (Scheibling *et al*., 2008), so gains some benefit from the presence of these species. However, the wave exposure of this biotope and the mobility of the substratum and the lack of tidepools may inhibit the colonization of this biotope by invasive, non-indigenous macroalgae.

A number of INIS that can settle and occupy hard substratum may threaten this biotope in the future if they become established. 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.

Sensitivity assessment. Overall, there is little evidence of this biotope being adversely affected by non-native species. Resistance Is therefore assessed as ‘High’ and recovery as ‘High’ (by default) so that the biotope is assessed as ‘Not sensitive’. Changes in the identities, distribution or abundance of INIS may require this assessment to be updated.

Introduction of microbial pathogens	Medium Q: High A: Low C: Low	High Q: High A: Low C: Medium	Low Q: High A: Low C: Low

The characterizing species, littorinids, *Semibalanus balanoides* and *Patella vulgata* are considered subject to persistent, low levels of infection by pathogens and parasites. Barnacles are parasitised by a variety of organisms and, in particular, the cryptoniscid isopod *Hemioniscus balani*, in which heavy infestation can cause castration of the barnacle. At usual levels of infestation these are not considered to lead to high levels of mortality. *Patella vulgata* has been reported to be infected by the protozoan *Urceolaria patellae* (Brouardel, 1948) at sites sheltered from extreme wave action in Orkney. Baxter (1984) found shells to be infested with two boring organisms, the polychaete *Polydora ciliata* and a siliceous sponge *Cliona celata*. 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 (Stefaniak *et al*., 2005).

Sensitivity assessment. Based on the characterizing species and the lack of evidence for widespread, high-levels of mortality due to microbial pathogens the biotope is considered to have 'High' resistance to this pressure and therefore 'High' resilience (by default), the biotope is therefore considered to be 'Not sensitive'.

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

Littorinids are one of the most commonly harvested species of the rocky shore. Large scale removal of *Littorina littorea* may allow a proliferation of opportunistic green algae, such as *Ulva*, on which it preferentially feeds. The community structure within the biotope is likely to be altered but some individuals are likely to remain.

Experiments designed to test the effects of harvesting by removing individuals at Strangford Lough found that there was no effect of experimental treatments (either harvesting or simulated disturbance) on *Littorina littorea* abundance or body size over a 12 week period (Crossthwaite *et al*. 2012). This suggests that these animals are generally abundant and highly mobile; thus, animals that were removed were quickly replaced by dispersal from surrounding, un-harvested areas. However, long-term exploitation, as inferred by background levels of harvest intensity, did significantly influence population abundance and age structure (Crossthwaite *et al*. 2012). A broadscale study of harvesting in Ireland using field studies and interviews with wholesalers and pickers did suggest that some areas were over harvested but the lack of background data and quantitative records make this assertion difficult to test (Cummins *et al*., 2002).

Sensitivity assessment. In general, collectors will be efficient at removing this littorinids and resistance is, therefore, assessed as **'Low'** (removal is not considered to be total as smaller individuals may escape) and recovery is assessed as **'High'** based on above evidence (Crossthwaite *et al*., 2012), so that 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 enhanced algal growth although the mobility of the boulders and cobbles may counteract the development of all but ephemeral, opportunistic algae.

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

Removal of the characterizing limpets, littorinids and barnacles and the red seaweeds would alter the character of the biotope. Removal of these species may result in the proliferation of ephemeral green algae, altering the character of the community.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope, so that it was bare rock. Resistance is, therefore, assessed as **'Low'** and resilience as **'Medium',** so that sensitivity is assessed as **'Medium'**.

Bibliography

Airoldi, L., 2003. The effects of sedimentation on rocky coast assemblages. *Oceanography and Marine Biology: An Annual Review*, **41**,161-236

Airoldi, L. & Hawkins, S.J., 2007. Negative effects of sediment deposition on grazing activity and survival of the limpet *Patella vulgata*. *Marine Ecology Progress Series*, **332**, 235-240.

Albrecht, A. & Reise, K., 1994. Effects of *Fucus vesiculosus* covering intertidal mussel beds in the Wadden Sea. *Helgoländer Meeresuntersuchungen*, **48** (2-3), 243-256.

Arnold, D., 1957. The response of the limpet, *Patella vulgata* L., to waters of different salinities. *Journal of the Marine Biological Association of the United Kingdom*, **36** (01), 121-128.

Barnes, H., 1956. *Balanus balanoides* (L.) in the Firth of Clyde: the development and annual variation in the larval population and the causative factors. *Journal of Animal Ecology*, **25**, 72-84.

Barnes, H. & Stone, R., 1972. Suppression of penis development in *Balanus balanoides* (L.). *Journal of Experimental Marine Biology and Ecology*, **9** **(**3), 303-309.

Barnes, H., 1957. Processes of restoration and synchronization in marine ecology. The spring diatom increase and the 'spawning' of the common barnacle *Balanus balanoides* (L.). *Année Biologique. Paris*, **33**, 68-85.

Barnes, H., 1963. Light, temperature and the breeding of *Balanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, **43** (03), 717-727.

Barnes, H., Finlayson, D.M. & Piatigorsky, J., 1963. The effect of desiccation and anaerobic conditions on the behaviour, survival and general metabolism of three common cirripedes. *Journal of Animal Ecology*, **32**, 233-252.

Bauer, B., Fioroni, P., Ide, I., Liebe, S., Oehlmann, J., Stroben, E. & Watermann, B., 1995. TBT effects on the female genital system of *Littorina littorea*: a possible indicator of tributyl tin pollution. *Hydrobiologia*, **309**, 15-27.

Baxter, J.M., 1984. The incidence of *Polydora ciliata* and *Cliona celata* boring the shell of *Patella vulgata* in Orkney. *Journal of the Marine Biological Association of the United Kingdom*, **64**, 728-729.

Bennell, S.J., 1981. Some observations on the littoral barnacle populations of North Wales. *Marine Environmental Research*, **5**, 227-240.

Bertness, M.D., 1984. Habitat and community modification by an introduced herbivorous snail. *Ecology*, **65**, 370-381.

Bertness, M.D., Gaines, S.D., Bermudez, D. & Sanford, E., 1991. Extreme spatial variation in the growth and reproductive output of the acorn barnacle *Semibalanus balanoides*. *Marine Ecology Progress Series*, 75, 91-100.

Bertocci, I., Araujo, R., Vaselli, S. & Sousa-Pinto, I., 2011. Marginal populations under pressure: spatial and temporal heterogeneity of *Ascophyllum nodosum* and associated assemblages affected by human trampling in Portugal. Marine Ecology Progress Series, **439**, 73-82.

Bishop, J. 2012c. Carpet Sea-squirt, *Didemnum vexillum.Great Britain Non-native Species Secretariat* [On-line]. [cited 30/10/2018]. Available from: http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1209

Bishop, J. 2015a. Compass sea squirt, *Asterocarpa humilis*. *Great Britain Non-native Species Secretariat*. [On-line] [cited 16/06/2015]. Available from: <http://www.nonnativespecies.org

Bishop, J. 2015b. *Watersipora subatra*. *Great Britain Non-native Species Secretariat*. [On-line][cited 16/06/2015]. Available from: <http://www.nonnativespecies.org

Blackmore, D.T., 1969. Growth, reproduction and zonation of *Patella vulgata*. *Journal of Experimental Marine Biology and Ecology*, **3**, 200-213.

Bonner, T. M., Pyatt, F. B. & Storey, D. M., 1993. Studies on the motility of the limpet *Patella vulgata* in acidified sea-water. *International Journal of Environmental Studies*, **43**, 313-320.

Bowman, R.S., 1985. The biology of the limpet *Patella vulgata* L. in the British Isles: spawning time as a factor determining recruitment sucess. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc.*, (ed. P.G. Moore & R. Seed), Hodder and Stoughton, London, pages 178-193.

Bowman, R.S. and Lewis, J.R., 1986. Geographical variation in the breeding cycles and recruitment of *Patella* spp. *Hydrobiologia*, **142**, 41-56.

Brosnan, D.M. & Crumrine, L.L., 1994. Effects of human trampling on marine rocky shore communities. *Journal of Experimental Marine Biology and Ecology*, **177**, 79-97.

Brouardel, J., 1948. Etude du mode d'infestation des Patelles par *Urceolaria patellae* (Cuenot): influence de l'espece de Patelle. *Bulletin du Laboratoire maritime de Dinard*, **30**, 1-6.

Brousseau, D.J. & Goldberg, R., 2007. Effect of predation by the invasive crab *Hemigrapsus sanguineus* on recruiting barnacles *Semibalanus balanoides* in western Long Island Sound, USA. *Marine Ecology Progress Series*, **339**, 221-228.

Bryan, G.W. & Gibbs, P.E., 1983. *Heavy metals from the Fal estuary, Cornwall: a study of long-term contamination by mining waste and its effects on estuarine organisms.* Plymouth: Marine Biological Association of the United Kingdom. [Occasional Publication, no. 2.]

Bryan, G.W., 1984. Pollution due to heavy metals and their compounds. In *Marine Ecology: A Comprehensive, Integrated Treatise on*

Life in the Oceans and Coastal Waters, vol. 5. *Ocean Management*, part 3, (ed. O. Kinne), pp.1289-1431. New York: John Wiley & Sons.

Bryan, G.W., Langston, W.J., Hummerstone, L.G., Burt, G.R. & Ho, Y.B., 1983. An assessment of the gastropod *Littorina littorea* (L.) as an indicator of heavy metal contamination in United Kingdom estuaries. *Journal of the Marine Biological Association of the United Kingdom*, **63**, 327-345.

Cabral-Oliveira, J., Mendes, S., Maranhão, P. & Pardal, M., 2014. Effects of sewage pollution on the structure of rocky shore macroinvertebrate assemblages. *Hydrobiologia*, **726** (1), 271-283.

Carlson, R.L., Shulman, M.J. & Ellis, J.C., 2006. Factors Contributing to Spatial Heterogeneity in the Abundance of the Common Periwinkle *Littorina Littorea* (L.). *Journal of Molluscan Studies*, **72** (2), 149-156.

Casey, J.D., De Grave, S. & Burnell, G.M., 1998. Intersex and *Littorina littorea* in Cork Harbour: results of a medium-term monitoring programme. *Hydrobiologia*, **378**, 193-197.

Chandrasekara, W.U. & Frid, C.L.J., 1998. A laboratory assessment of the survival and vertical movement of two epibenthic gastropod species, *Hydrobia ulvae*, (Pennant) and *Littorina littorea* (Linnaeus), after burial in sediment. *Journal of Experimental Marine Biology and Ecology*, **221**, 191-207.

Cole, S., Codling, I.D., Parr, W., Zabel, T., 1999. Guidelines for managing water quality impacts within UK European marine sites [On-line]. *UK Marine SACs Project*. [Cited 26/01/16]. Available from: http://www.ukmarinesac.org.uk/pdfs/water_quality.pdf

Connell, J.H., 1961. Effects of competition, predation by *Thais lapillus*, and other factors on natural populations of the barnacle *Balanus balanoides*. *Ecological Monographs*, **31**, 61-104.

Connor, D., Allen, J., Golding, N., Howell, K., Lieberknecht, L., Northen, K. & Reker, J., 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough. ISBN 1 861 07561 8.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03.* [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from https://mhc.jncc.gov.uk/

Crisp, D. & Patel, B., 1969. Environmental control of the breeding of three boreo-arctic cirripedes. *Marine Biology*, **2** (3), 283-295.

Crisp, D.J. & Southward, A.J., 1961. Different types of cirral activity *Philosophical Transactions of the Royal Society of London, Series B*, **243**, 271-308.

Crisp, D.J. (ed.), 1964. The effects of the severe winter of 1962-63 on marine life in Britain. *Journal of Animal Ecology*, **33**, 165-210.

Crossthwaite, S.J., Reid, N. & Sigwart, J.D., 2012. Assessing the impact of shore-based shellfish collection on under-boulder communities in Strangford Lough. *Report prepared by the Natural Heritage Research Partnership (NHRP) between Quercus, Queen's University Belfast and the Northern Ireland Environment Agency (NIEA) for the Research and Development Series* No. 13/03.

Crothers, J., 1992. Shell size and shape variation in *Littorina littorea* (L.) from west Somerset. *Proceedings of the Third International Symposium on Littorinid Biology*, J. Grahame, PJ Mill and D. G. Reid (eds.). *The Malacological Society of London*, pp. 91-97.

Cummins, V., Coughlan, S., McClean, O., Connolly, N., Mercer, J. & Burnell, G., 2002. An assessment of the potential for the sustainable development of the edible periwinkle, *Littorina littorea*, industry in Ireland.*Report by the Coastal and Marine Resources Centre, Environmental Research Institute*, University College Cork.

Daly, M.A. & Mathieson, A.C., 1977. The effects of sand movement on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire, USA. *Marine Biology*, **43**, 45-55.

Davenport, J. & Davenport, J.L., 2005. Effects of shore height, wave exposure and geographical distance on thermal niche width of intertidal fauna. *Marine Ecology Progress Series*, **292**, 41-50.

Davenport, J., Berggren, M.S., Brattegard, T., Brattenborg, N., Burrows, M., Jenkins, S., McGrath, D., MacNamara, R., Sneli, J.-A. & Walker, G., 2005. Doses of darkness control latitudinal differences in breeding date in the barnacle *Semibalanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, **85** (01), 59-63.

Davies, M.S., 1992. Heavy metals in seawater: effects on limpet pedal mucus production. *Water Research*, **26**, 1691-1693.

Davies, S.P., 1970. Physiological ecology of *Patella* IV. Environmental and limpet body temperatures. *Journal of the Marine Biological Association of the United Kingdom*, **50** (04), 1069-1077.

Deutsch, U. & Fioroni, P., 1996. Effects of tributyltin (TBT) and testosterone on the female genital system in the mesogastropod *Littorina littorea* (Prosobranchia). *Helgolander Meeresuntersuchungen*, **50**, 105-115.

Diaz, E.R., Kraufvelin, P. & Erlandsson, J., 2012. Combining gut fluorescence technique and spatial analysis to determine *Littorina littorea* grazing dynamics in nutrient-enriched and nutrient-unenriched littoral mesocosms. *Marine Biology*, **159** (4), 837-852.

Ekaratne, S.U.K. & Crisp, D.J., 1984. Seasonal growth studies of intertidal gastropods from shell micro-growth band measurements, including a comparison with alternative methods. *Journal of the Marine Biological Association of the United Kingdom*, **64**, 183-210.

Eschweiler, N. & Buschbaum, C., 2011. Alien epibiont (*Crassostrea gigas)* impacts on native periwinkles (*Littorina littorea*). *Aquatic Invasions*, **6** (3), 281-290.

Evans, R.G., 1948. The lethal temperatures of some common British littoral molluscs. *The Journal of Animal Ecology*, **17**, 165-173.

Foster, B.A., 1970. Responses and acclimation to salinity in the adults of some balanomorph barnacles. *Philosophical Transactions* *of the Royal Society of London, Series B*, **256**, 377-400.

Foster, B.A., 1971b. On the determinants of the upper limit of intertidal distribution of barnacles. *Journal of Animal Ecology*, **40**, 33-48.

Foster, P., Hunt, D.T.E. & Morris, A.W., 1978. Metals in an acid mine stream and estuary. *Science of the Total Environment*, **9**, 75-86.

Fretter, V. & Graham, A., 1994. *British prosobranch molluscs: their functional anatomy and ecology*, revised and updated edition. London: The Ray Society.

Gallagher, M.C., Davenport, J., Gregory, S., McAllen, R. & O'Riordan, R., 2015. The invasive barnacle species, *Austrominius modestus*: Its status and competition with indigenous barnacles on the Isle of Cumbrae, Scotland. *Estuarine, Coastal and Shelf Science*, **152**, 134-141.

Glegg, G. A., Hickman, L. & Rowland, S. J., 1999. Contamination of limpets (*Patella vulgata*) following the Sea Empress oil spill. *Marine Pollution Bulletin*, **38**, 119-125.

Gomes-Filho, J., Hawkins, S., Aquino-Souza, R. & Thompson, R., 2010. Distribution of barnacles and dominance of the introduced species *Elminius modestus* along two estuaries in South-West England. *Marine Biodiversity Records*, **3**, e58.

Grandy, N., 1984. *The effects of oil and dispersants on subtidal red algae*. Ph.D. Thesis. University of Liverpool.

Grenon, J.F. & Walker, G., 1981. The tenacity of the limpet, *Patella vulgata* L.: an experimental approach. *Journal of Experimental Marine Biology and Ecology*, **54**, 277-308.

Gyory, J. & Pineda, J., 2011. High-frequency observations of early-stage larval abundance: do storms trigger synchronous larval release in *Semibalanus balanoides? Marine Biology*, **158** (7), 1581-1589.

Gyory, J., Pineda, J. & Solow, A., 2013. Turbidity triggers larval release by the intertidal barnacle *Semibalanus balanoides*. *Marine Ecology Progress Series*, **476**, 141-151.

Hatton,H., 1938. Easelsde bionomie explicative surquelques especesintercotidalesd'algues et d'animaux. *Annales de l'Institut Oceanographique* **17**: 241-348

Hawkins, S., 1983. Interactions of *Patella* and macroalgae with settling *Semibalanus balanoides* (L.). *Journal of Experimental Marine Biology and Ecology*, **71** (1), 55-72.

Hawkins, S.J. & Hartnoll, R.G., 1985. Factors determining the upper limits of intertidal canopy-forming algae. *Marine Ecology Progress Series*, **20**, 265-271.

Hawkins, S.J. & Southward, A.J., 1992. The *Torrey Canyon* oil spill: recovery of rocky shore communities. In *Restoring the Nations Marine Environment, (ed. G.W. Thorpe), Chapter 13, pp. 583-631*. Maryland, USA: Maryland Sea Grant College.

Hills, J. & Thomason, J., 1998. The effect of scales of surface roughness on the settlement of barnacle (*Semibalanus balanoides*) cyprids. *Biofouling*, **12** (1-3), 57-69.

Hoare, R. & Hiscock, K., 1974. An ecological survey of the rocky coast adjacent to the effluent of a bromine extraction plant. *Estuarine and Coastal Marine Science*, **2** (4), 329-348.

Holmes, S.P., Walker, G. & van der Meer, J., 2005. Barnacles, limpets and periwinkles: the effects of direct and indirect interactions on cyprid settlement and success. *Journal of Sea Research*, **53** (3), 181-204.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G., 1995. The sensitivity of marine communities to man induced change - a scoping report. *Countryside Council for Wales, Bangor, Contract Science Report*, no. 65.

Jenkins, S., Åberg, P., Cervin, G., Coleman, R., Delany, J., Della Santina, P., Hawkins, S., LaCroix, E., Myers, A. & Lindegarth, M., 2000. Spatial and temporal variation in settlement and recruitment of the intertidal barnacle *Semibalanus balanoides* (L.)(Crustacea: Cirripedia) over a European scale. *Journal of Experimental Marine Biology and Ecology*, **243** (2), 209-225.

Jenkins, S.R., Beukers-Stewart, B.D. & Brand, A.R., 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. *Marine Ecology Progress Series*, **215**, 297-301.

Jenkins, S.R., Hawkins, S.J. & Norton, T.A., 1999. Direct and indirect effects of a macroalgal canopy and limpet grazing in structuring a sheltered inter-tidal community. *Marine Ecology Progress Series*, **188**, 81-92.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

Kendall, M.A., Bowman, R.S., Williamson, P. & Lewis, J.R., 1985. Annual variation in the recruitment of *Semibalanus balanoides* on the North Yorkshire coast 1969-1981. *Journal of the Marine Biological Association of the United Kingdom*, **65**, 1009-1030.

Landes, A. & Zimmer, M., 2012. Acidification and warming affect both a calcifying predator and prey, but not their interaction. *Marine Ecology Progress Series*, **450**, 1-10.

Langston, W.J. & Zhou Mingjiang, 1986. Evaluation of the significance of metal-binding proteins in the gastropod *Littorina littorea*. *Marine Biology*, **92**, 505-515.

Leonard, G.H., Levine, J.M., Schmidt, P.R. & Bertness, M.D., 1998. Flow-driven variation in intertidal community structure in a Maine estuary. *Ecology*, **79** (4), 1395-1411.

Le Quesne W.J.F. 2005. *The response of a protandrous species to exploitation, and the implications for management: a case study with patellid limpets*. PhD thesis. University of Southampton, Southampton, United Kingdom.

Lewis, J. & Bowman, R.S., 1975. Local habitat-induced variations in the population dynamics of *Patella vulgata* L. *Journal of Experimental Marine Biology and Ecology*, **17** (2), 165-203.

Little, C., Partridge, J.C. & Teagle, L., 1991. Foraging activity of limpets in normal and abnormal tidal regimes. *Journal of the Marine Biological Association of the United Kingdom*, **71**, 537-554.

Littler, M.M., Martz, D.R. & Littler, D.S., 1983. Effects of recurrent sand deposition on rocky intertidal organisms: importance of substrate heterogeneity in a fluctuating environment. *Marine Ecology Progress Series*. **11** (2), 129-139.

Long, J.D., Cochrane, E. & Dolecal, R., 2011. Previous disturbance enhances the negative effects of trampling on barnacles. *Marine Ecology Progress Series*, **437**, 165-173.

Marchan, S., Davies, M.S., Fleming, S. & Jones, H.D., 1999. Effects of copper and zinc on the heart rate of the limpet *Patella vulgata* (L.) *Comparative Biochemistry and Physiology*, **123A**, 89-93.

Markert, A., Wehrmann, A. & Kröncke, I., 2010. Recently established *Crassostrea*-reefs versus native *Mytilus*-beds: differences in ecosystem engineering affects the macrofaunal communities (Wadden Sea of Lower Saxony, southern German Bight). *Biological Invasions*, **12** (1), 15-32.

Marshall, D.J. & McQuaid, C.D., 1989. The influence of respiratory responses on the tolerance to sand inundation of the limpets *Patella granularis* L.(Prosobranchia) and *Siphonaria capensis* Q. et G.(Pulmonata). *Journal of Experimental Marine Biology and Ecology*, **128** (3), 191-201.

Marshall, D.J. & McQuaid, C.D., 1993. Effects of hypoxia and hyposalinity on the heart beat of the intertidal limpets *Patella granvlaris* (Prosobranchia) and *Siphonaria capensis* (Pulmonata). *Comparative Biochemistry and Physiology Part A: Physiology*, **106** (1), 65-68

Mieszkowska, N., Burrows, M.T., Pannacciulli, F.G. & Hawkins, S.J., 2014. Multidecadal signals within co-occurring intertidal barnacles *Semibalanus balanoides* and *Chthamalus* spp. linked to the Atlantic Multidecadal Oscillation. *Journal of Marine Systems*, **133**, 70-76.

Moore, J., 1997. *Rocky shore transect monitoring in Milford Haven, October 1996. Impacts of the Sea Empress oil spill.* Countryside Council for Wales Sea Empress Contract Report, **241**, 90pp.

Murphy, D., 1983. Freezing resistance in intertidal invertebrates. *Annual review of physiology*, **45** (1), 289-299.

Newell, R.C., 1979. *Biology of intertidal animals*. Faversham: Marine Ecological Surveys Ltd.

O'Brien, P.J. & Dixon, P.S., 1976. Effects of oils and oil components on algae: a review. *British Phycological Journal*, **11**, 115-142.

Oehlmann, J., Bauer, B., Minchin, D., Schulte-Oehlmann, U., Fioroni, P. & Markert, B., 1998. Imposex in *Nucella lapillus* and intersex in *Littorina littorea*: interspecific comparison of two TBT- induced effects and their geographical uniformity. *Hydrobiologia*, **378**, 199-213

Petpiroon, S. & Dicks, B., 1982. Environmental effects (1969 to 1981) of a refinery effluent discharged into Littlewick Bay, Milford Haven. *Field Studies*, **5**, 623-641.

Petraitis, P.S. & Dudgeon, S.R., 2005. Divergent succession and implications for alternative states on rocky intertidal shores. *Journal of Experimental Marine Biology and Ecology*, **326** (1), 14-26.

Petraitis, P.S., Rhile, E.C. & Dudgeon, S., 2003. Survivorship of juvenile barnacles and mussels: spatial dependence and the origin of alternative communities. *Journal of Experimental Marine Biology and Ecology*, **293** (2), 217-236.

Povey, A. & Keough, M.J., 1991. Effects of trampling on plant and animal populations on rocky shores. *Oikos*, **61**: 355-368.

Prendergast, G.S., Zurn, C.M., Bers, A.V., Head, R.M., Hansson, L.J. & Thomason, J.C., 2009. The relative magnitude of the effects of biological and physical settlement cues for cypris larvae of the acorn barnacle, *Semibalanus balanoides* L. *Biofouling*, **25** (1), 35-44.

Raffaelli, D., 1982. Recent ecological research on some European species of *Littorina*. *Journal of Molluscan Studies*, **48** (3), 342-354.

Raffaelli, D. & Hawkins, S., 1999. *Intertidal Ecology* 2nd edn.. London: Kluwer Academic Publishers.

Rainbow, P.S., 1984. An introduction to the biology of British littoral barnacles. *Field Studies*, **6**, 1-51.

Ribeiro, P.A., Xavier, R., Santos, A.M. & Hawkins, S.J., 2009. Reproductive cycles of four species of *Patella* (Mollusca: Gastropoda) on the northern and central Portuguese coast. *Journal of the Marine Biological Association of the United Kingdom*, **89** (06), 1215-1221.

Rognstad, R.L., Wethey, D.S. & Hilbish, T.J., 2014. Connectivity and population repatriation: limitations of climate and input into the larval pool. *Marine Ecology Progress Series*, **495**, 175-183.

Safriel, U.N., Erez, N. & Keasar, T., 1994. How do limpets maintain barnacle-free submerged artificial surfaces? *Bulletin of Marine Science*, **54** (1), 17-23.

Sanford, E., Bermudez, D., Bertness, M.D. & Gaines, S.D., 1994. Flow, food supply and acorn barnacle population dynamics. *Marine Ecology Progress Series*, **104**, 49-49.

Scheibling, R.E., Lyons, D.A. & Sumi, C.B., 2008. Grazing of the invasive alga *Codium fragile* ssp. *tomentosoides* by the common periwinkle *Littorina littorea*: effects of thallus size, age and condition. *Journal of Experimental Marine Biology and Ecology*, **355** (2), 103-113.

Seed, R. & Suchanek, T.H., 1992. Population and community ecology of *Mytilus*. In *The mussel* Mytilus*: ecology, physiology, genetics and culture,* (ed. E.M. Gosling), pp. 87-169. Amsterdam: Elsevier Science Publ. [Developments in Aquaculture and Fisheries Science, no. 25.]

Shanks, A.L. & Wright, W.G., 1986. Adding teeth to wave action- the destructive effects of wave-bourne rocks on intertidal organisms. *Oecologia*, **69** (3), 420-428.

Smith, J.E. (ed.), 1968. 'Torrey Canyon'. *Pollution and marine life.* Cambridge: Cambridge University Press.

Southward, A.J. & Southward, E.C., 1978. Recolonisation of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. *Journal of the Fisheries Research Board of Canada*, **35**, 682-706.

Southward, A.J., Hawkins, S.J. & Burrows, M.T., 1995. Seventy years observations of changes in distribution and abundance of zooplankton and intertidal organisms in the western English Channel in relation to rising sea temperature. *Journal of Thermal Biology*, **20**, 127-155.

Stefaniak, L.M., McAtee, J. & Shulman, M.J., 2005. The costs of being bored: Effects of a clionid sponge on the gastropod *Littorina littorea* (L). *Journal of Experimental Marine Biology and Ecology*, **327** (1), 103-114.

Storey, K.B., Lant, B., Anozie, O.O. & Storey, J.M., 2013. Metabolic mechanisms for anoxia tolerance and freezing survival in the intertidal gastropod, *Littorina littorea*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, **165** (4), 448-459.

Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.

Svåsand, T., Crosetti, D., García-Vázquez, E. & Verspoor, E., 2007. Genetic impact of aquaculture activities on native populations. *Genimpact final scientific report (EU contract n. RICA-CT-2005-022802).*

Sweet, N.S. & Sewell, J. 2014. Asian shore crab, *Hemigrapsus sanguineus*. *Great Britain Non-native Species Secretariat*. [cited 16/06/2015]. Available from: <http://www.nonnativespecies.org

Terry, L. & Sell, D., 1986. Rocky shores in the Moray Firth. *Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences*, **91**, 169-191.

Thompson, G.B., 1980. Distribution and population dynamics of the limpet *Patella vulgata* in Bantry Bay. *Journal of Experimental Marine Biology and Ecology*, **45**, 173-217.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W., McGonigle, D. & Russell, A.E., 2004. Lost at sea: where is all the plastic? *Science*, **304** (5672), 838-838.

Tighe-Ford, D., 1967. Possible mechanism for the endocrine control of breeding in a cirripede. *Nature*, **216**, 920-921.

Tyler-Walters, H. & Arnold, C., 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. *Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN) [Contract no. FC 73-03-327]*, Marine Biological Association of the UK, Plymouth, 48 pp. Available from: www.marlin.ac.uk/publications

Valentine, P.C., Carman, M.R., Blackwood, D.S. & Heffron, E.J., 2007. Ecological observations on the colonial ascidian *Didemnum* sp. in a New England tide pool habitat. *Journal of Experimental Marine Biology and Ecology*, **342** (1), 109-121.

Wethey, D.S., 1985. Catastrophe, Extinction, and Species Diversity: A Rocky Intertidal Example. *Ecology*, **66** (2), 445-456.

Wethey, D.S., 1984. Sun and shade mediate competition in the barnacles *Chthamalus* and *Semibalanus*: a field experiment. *The Biological Bulletin*, **167** (1), 176-185.

Wethey, D.S., Woodin, S.A., Hilbish, T.J., Jones, S.J., Lima, F.P. & Brannock, P.M., 2011. Response of intertidal populations to climate: effects of extreme events versus long term change. *Journal of Experimental Marine Biology and Ecology*, **400** (1), 132-144.

Withers, R., Farnham, W., Lewey, S., Jephson, N., Haythorn, J. & Gray, P., 1975. The epibionts of *Sargassum muticum* in British waters. *Marine Biology*, **31** (1), 79-86.

Wood, C., 2015. The red ripple bryozoan *Watersipora subatra*. *Great Britain Non-native Species Secretariat*. [On-line][cited 16/06/2015]. Available from: http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=3748