Talitrids on the upper shore and strand-line

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

Dr Heidi Tillin & Georgina Budd

2004-10-27

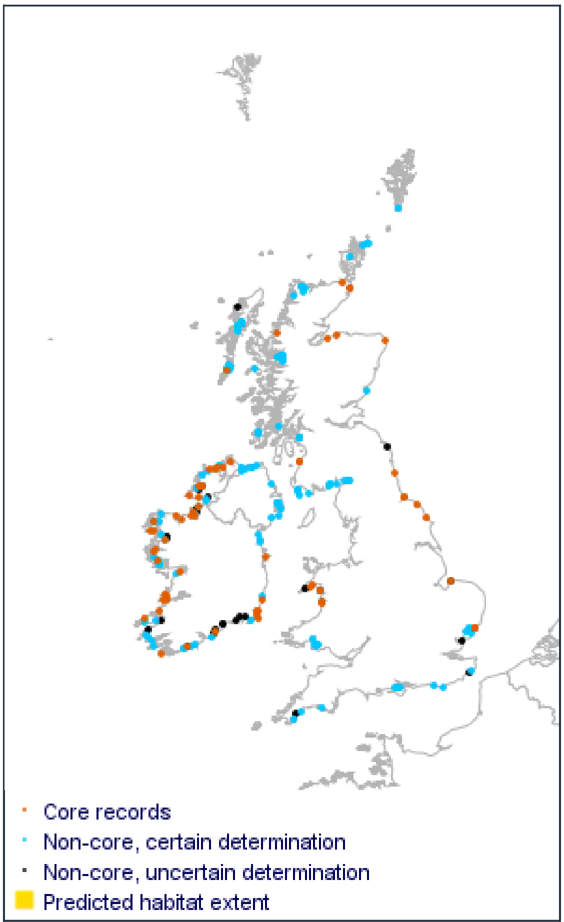
A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/176]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Tillin, H.M. & Budd, G., 2004. Talitrids on the upper shore and strand-line. 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.176.1

The information (TEXT ONLY) provided by the Marine Life Information Network (MarLIN) is licensed under a Creative Commons Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License. Note that images and other media featured on this page are each governed by their own terms and conditions and they may or may not be available for reuse. Permissions beyond the scope of this license are available here. Based on a work at www.marlin.ac.uk

Strandline of seawed and driftwood (LGS.Tal).
Photographer: Keith Hiscock
Copyright: Dr Keith Hiscock



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

Researched by Dr Heidi Tillin & Georgina Budd **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A2.211	Talitrids on the upper shore and strandline
JNCC 2015	LS.LSa.St.Tal	Talitrids on the upper shore and strand-line
JNCC 2004	LS.LSa.St.Tal	Talitrids on the upper shore and strand-line
1997 Biotope	LS.LGS.S.Tal	Talitrid amphipods in decomposing seaweed on the strand-line

Description

A community of sandhoppers (talitrid amphipods) may occur on any shore where driftlines of decomposing seaweed and other debris accumulate on the strandline. The biotope occurs most frequently on medium and fine sandy shores, but may also occur on a wide variety of sediment shores composed of muddy sediment, shingle and mixed substrata, or on rocky shores. The decaying seaweed provides cover and humidity for the sandhopper *Talitrus saltator*. In places on sand that regularly accumulate larger amounts of weed, *Talorchestia deshayesii* is often present.

Oligochaetes, mainly enchytraeids, can occur where the stranded debris remains damp as a result of freshwater seepage across the shore or mass accumulation of weed in shaded situations. On shingle and gravel shores and behind saltmarshes the strandline talitrid species tend to be mainly *Orchestia* species. Abundances of the characterising species tend to be highly patchy (JNCC, 2015).

Depth range

Strandline, Upper shore, Mid shore

Additional information

Strand-lines are ephemeral habitats owing to the methods of their formation, but may be more permanent and extensive features particularly in sheltered embayments or estuaries. The strand-line is a fringe habitat, neither fully marine nor terrestrial, it is consequently colonized by invertebrates from both ecosystems. On exposed shores the strand-line is of particular importance because it acts as a precursor to sand dunes. Strand-lines enhance the stabilization of the foreshore by supplementing the organic and moisture content of the substratum so that pioneering plants such as sea sandwort, *Honkenya peploides*, sea rocket, *Cakile maritima*, and saltwort, *Salsola kali* may eventually establish (Shackley & Llewellyn, 1997). This 'open tall herb community' develops best on shores that receive large inputs of detached macroalgae and windblown sand (Ignaciuk & Lee, 1980). Such plants trap sand and favour the development of embryo dunes and subsequent fore dunes (Salisbury, 1952; Chapman, 1976; Davidson *et al.*, 1991). In areas subjected to intensive recreational use and consequently where mechanical beach cleaning is practised, dune formation and stability could be adversely affected (Davidson *et al.*, 1991).

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- Of marine invertebrates, the order Amphipoda (sand hoppers) is dominant in the biotope. Three genera are common amongst the strand-line, *Talitrus*, *Talorchestia* and *Orchestia*, feeding on the stranded seaweed. Such amphipods are responsible for most of the primary consumption of surface material. The feeding activity of the amphipods serves to fragment algal matter (Harrison, 1977). Fragmentation has been identified as being central to the control of decomposition rates and subsequently the productivity of food chains based on algal material (Robertson & Mann, 1980). Fragmentation of macroalgae increases the decomposition rate by reducing particle size, allowing a greater surface area for microbial action and the excretion of nitrogen rich materials enhances microbial growth (Robertson & Mann, 1980).
- Large numbers of Coleoptera such as the black, smooth ground beetle, *Broscus cephalotes*, and the scarce *Nebria complanata* (restricted to the south west: Davidson *et al.*, 1991; Fowles, 1994), frequent the biotope to feed on talitrids and insect larvae (Llewellyn & Shackley, 1996). Several species of darkling beetles (Tenebrionidae) and rove beetles (Staphylinidae), live in the sand several centimetres below the strand-line deposits.
- Koop & Griffiths (1982) reported a distinct relationship between the distribution of strand-line macro and meio- fauna and their food source: >82% of the biomass of both groups was concentrated beneath the most recent strand-line on a beach on the Cape Peninsula, South Africa.
- Mites of the genera Halolaelaps and Phaulodinychus (Gamasida), in addition to the Histiostoma (Acaridida) (Acarina: Chelicerata), occur in strand-line debris. All three mites disperse between strand-lines via talitrid amphipods. Talitrid amphipods offer two principle advantages over insect hosts. Firstly, talitrid amphipods, such as *Talitrus saltator*, migrate between strand-lines throughout the year allowing continual mite dispersal and secondly juvenile talidrids are sufficiently large to support several mites (Pugh *et al.*, 1997).
- Large numbers of birds feed along the strand-line at certain times of year, including waders, corvids and passerines, in addition to many seabirds (Pienkowski, 1982; Cramp & Simmons, 1983; Lack, 1986, Cramp, 1988; Davidson *et al.*, 1991).
- Terrestrial mammals such as foxes, voles, mice and rats also frequent the strand-line to feed (Shackley & Llewellyn, 1997).

Seasonal and longer term change

- The biotope is ephemeral. The amount of macroalgae stranded on the shore is likely to vary seasonally, with deposits being particularly plentiful after winter storms that dislodge algae from the rocks.
- Griffiths & Stenton-Dozey (1981) attempted to follow successional changes in the fauna of strand-line algal detritus and changes in its condition.
  - Bacteria colonized the stranded macroalgae within 24 hours (Koop & Lucas, 1983).
  - Amphipods and dipteran flies dominated the biomass during the early stages, followed by beetles later on as the algae dried.
  - Changes were apparent between algal debris that had been deposited singly and

that deposited in banks. Both types of deposit lost half of their dry mass within the first seven days following stranding indicating a rapid rate of utilization by consumer organisms.
    - Single strands of algae lost moisture more rapidly than banked algae. For instance, the moisture content of single strands fell from 80% at 3 days to 22% after 6 days, whilst banks of algae retained a moisture content of 53% after 6 days.
- Adults of the most common genus of dipterous flies, *Fucellia* and *Coelopa*, are always present, as they are opportunistic colonizers, able to move rapidly between strand-line deposits. However, they are exceptionally abundant in summer and autumn, coinciding with the presence of many larvae. This probably reflects a summer/autumn breeding peak (Stenton-Dozey & Griffiths, 1980).
- In Britain during the day, *Talitrus saltator* occurs above the high-tide line, either buried within the sand at depths of between 10-30 cm or within high shore deposits of stranded algae (Keith Hiscock, pers. comm..), prior to emerging at night to forage intertidally on the strand-line (Williams, 1983b). During the winter, quiescent populations are found burrowed above the extreme high water spring level (EHWS), as deep as 50 -100 cm (Bregazzi & Naylor, 1972; Williams, 1976)

Habitat structure and complexity

On sandy shores, the strand-line is an ideal place for many species to live. The high organic content and water retaining capacity contrast with the relatively sterile and fast draining sand elsewhere. Seaweed in the strand-line is likely to be in various states of decay, older dryer material towards high water spring mark and fresh material towards low water, so that a plethora of microhabitats is available for colonization and utilization by the different life stages of different species, e.g. adult and juvenile wrack flies prefer different locations (see recruitment processes). In addition, differences in microclimate and decomposition rate exist between algae that is deposited in banks and algae deposited singly. The interstitial environment of the sand beneath the strand-line also differs to that of the surrounding area owing to the high concentrations of dissolved organic matter (DOM) (Koop & Griffiths, 1982).

Productivity

Several studies on South African beaches (Robertson & Mann, 1980; Koop & Griffiths, 1982; Koop *et al.*, 1982; Griffiths & Stenton-Dozey, 1981) have examined aspects of the roles of macrofauna, meiofauna and bacteria in the productivity of the strand-line environment.
Production is predominantly secondary. Carbon fixed during primary production by macroalgae in other habitats enters the detrital pathway, the decomposition of which is a key process in the channelling of energy and cycling of nutrients. The feeding activity of amphipods in particular serves to fragment algal detritus (Harrison, 1977). Fragmentation has been identified as being central to the control of decomposition rates and subsequently the productivity of food chains based on algal material (Robertson & Mann, 1980), its role in stream and lacustrine ecosystems has been well documented (e.g. Cummins, 1974). Fragmentation of macroalgae increases the decomposition rate by reducing particle size, allowing a greater surface area for microbial action and the excretion of nitrogen rich materials enhances microbial growth (Robertson & Mann, 1980). Whilst macro- and meiofauna play a vital role in fragmentation of organic particles, bacteria are overwhelmingly important in the productivity of strand-line ecosystems (Koop *et al.*, 1982). Annual turnover estimates (P/B) suggest that bacteria may account for about 87% of annual strand-line production, with meiofauna and macrofauna accounting for 10% and 3% respectively (Koop *et al.*,

1982).

Recruitment processes

Many marine and otherwise terrestrial species utilize the strand-line deposits of wrack as a refuge in which to breed. Within the strand-line algal debris, it is possible for the vulnerable juvenile life stages to survive in a favourable microclimate and ready supply of nourishment. For instance:

- The sand hopper, *Talitrus saltator* broods its eggs and has an annual univoltine reproductive cycle (one generation reaching maturity each year). As in all crustaceans, mating and the release of juveniles is synchronised with the moult cycle. Juveniles may be found from May through until September, but peak reproductive activity occurs in August. The breeding cycle in *Talitrus saltator* is shorter than in other intertidal amphipods and is controlled by daylength irrespective of air and sea temperature (Williams, 1978). Juveniles reach maturity before autumn, overwinter and breed the following summer.
- Terrestrial dipterous flies, especially *Fucellia maritima* and *Fucellia fucorum*, utilize the strand-line macroalgae for the deposition of their eggs. The flies favour the drier wrack beds, and three larval instars (stages between moults) are passed there prior to pupation. Larvae are not adapted to living in wet wrack owing to a lack of hairs on their posterior spiracles and large spines on the ventral surface which are present in other wrack flies. Emergence of adults is sudden towards the end of March and adults remain in abundance until the end of September (Egglishaw, 1960). In contrast to the larvae, adults are most attracted to wet wrack. Other flies, such as *Coelopa frigida*, *Coelopa pilipes* and *Thoracochaeta zosterae* breed in the wrack beds and would not be found on the shore but for the accumulations of wrack in which to live and breed (Eltringham, 1971).
- Some beetles and centipedes also complete their reproductive cycle in the wrack beds. The staphylinid beetle, *Bleduis spectabilis* burrows in the sand, its tunnels have a side chamber in which the larvae develop. Parents supply the larvae with food and ventilate the burrow. The centipede *Hydoschendyla submarina* has become wholly adapted to life in the littoral zone. The female lays eggs that are impermeable, and so are not affected osmotically if inundated by seawater (Eltringham, 1971).

Time for community to reach maturity

The biotope is ephemeral in nature, consequently in order to utilize the resources that the stranded debris provides, the community reaches maturity within a few weeks. Such rapid colonization is achievable owing to the fact that species of the community originate from both terrestrial (e.g. flies, centipedes and beetles) and marine (e.g. sand hoppers) environments so can migrate quickly from adjacent habitats.

Additional information

Amphipods, such as *Talitrus saltator*, are useful in strand-line population assessments and monitoring surveys (Shackley & Llewellyn, 1997). They are always present at and around the most recent high water strand-line deposit and possess a well defined endogenous and circadian locomotor activity pattern (Bregazzi, 1972; Bregazzi & Naylor, 1972; Williams, 1980) that controls their daily migration to recently deposited strand-line algae.

Preferences & Distribution

Habitat preferences

Depth Range	Strandline, Upper shore, Mid shore
Water clarity preferences	Field Unresearched
Limiting Nutrients	Field unresearched
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	Open coast
Biological zone preferences	Mid eulittoral, Supralittoral, Upper eulittoral
Substratum/habitat preferences	Gravel / shingle, Sand
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Moderately exposed, Sheltered, Very sheltered
Other preferences	Deposits of organic debris, especially macroalgae

Additional Information

LGS.Tal is an ephemeral habitat occurring where the tide carries and deposits seaweed and other debris. Such material will decompose, be transported elsewhere and the quantity vary owing to factors such as tidal cycle and prevailing weather conditions.

Species composition

Species found especially in this biotope

- *Armadillidium album*
- *Coelopa frigida*
- *Coelopa pilipes*
- *Enchytraeidae spp.*
- *Fucellia fucorum*
- *Fucellia maritima*
- *Orchestia gammarellus*
- *Talitrus saltator*
- *Talorchestia deshayessii*

Rare or scarce species associated with this biotope

- *Rumex rupestris*

Additional information

No text entered.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

A community of sandhoppers (talitrid amphipods) may occur on any shore where driftlines (also referred to as strandlines) of decomposing seaweed and other debris accumulate on the strandline. The biotope occurs most frequently on medium and fine sandy shores, but may also occur on a wide variety of sediment shores composed of muddy sediment, shingle and mixed substrata, or on rocky shores. The decaying seaweed provides cover and humidity for the sandhopper *Talitrus saltator*. In places on sand that regularly accumulate larger amounts of weed, *Talorchestia deshayesii* is often present. On shingle and gravel shores and behind saltmarshes the strandline talitrid species tend to be mainly *Orchestia* species. The talitrid amphipods are considered to characterize this biotope and the sensitivity assessments focus on this group. Amphipods can comprise 50–90% of the total macroinvertebrate fauna in beach-cast wrack (Behbehani & Croker, 1982).

Oligochaetes, mainly enchytraeids, can occur where the stranded debris remains damp as a result of freshwater seepage across the shore or mass accumulation of weed in shaded situations, but these are not considered characterizing species and their sensitivity is not assessed for this biotope. More information on oligochaete sensitivity is provided for the oligochaete dominated biotopes available on this website.

The driftline itself is considered within the sensitivity assessments as it provides the structural habitat that allows the biotope to develop.

Resilience and recovery rates of habitat

The strandline biotope is usually present but each deposit of macroalgae will be relatively short-lived and the strandline will move position on the beach, depending on tidal heights, and will also vary seasonally in location and size. Deposits are particularly plentiful after winter storms that dislodge algae from the rocks and deposit it high on the shore.

The characterizing species are mobile and able to orient themselves to find, or reposition in favourable habitats so that newly available deposits of macroalgae are therefore likely to be rapidly recolonized. Griffiths & Stenton-Dozey (1981) followed successional changes in the fauna of strand-line algal detritus and changes in its condition. Bacteria colonized the stranded macroalgae within 24 hours (Koop & Lucas, 1983). Amphipods and dipteran flies dominated the biomass during the early stages, followed by beetles later on as the algae dried.Adults of the most common genus of dipterous flies, *Fucellia* and *Coelopa*, are always present, as they are opportunistic colonizers, able to move rapidly between strand-line deposits. However, they are exceptionally abundant in summer and autumn, coinciding with the presence of many larvae. This probably reflects a summer/autumn breeding peak (Stenton-Dozey & Griffiths, 1980). In Britain during the day, the key characterizing species *Talitrus saltator* occurs above the high-tide line, either buried within the sand at depths of between 10-30 cm or within high shore deposits of stranded algae (Keith Hiscock, pers. comm..), prior to emerging at night to forage intertidally on the strand-line (Williams, 1983b). During the winter, quiescent populations are found burrowed above the extreme high water spring level (EHWS), as deep as 50 -100 cm (Bregazzi & Naylor, 1972; Williams, 1976). Amphipods, flies and bacteria are therefore very rapid colonizers of strandlines although some seasonal changes in activity occur, with reduced abundance/activity in the winter.

The key characterizing amphipod species*Talitrus saltator* broods its eggs and has an annual univoltine reproductive cycle (one generation reaching maturity each year). Juveniles may be found from May through until September, but peak reproductive activity occurs in August. The breeding cycle in Talitrus saltator is shorter than in other intertidal amphipods and is controlled by daylength irrespective of air and sea temperature (Williams, 1978). Juveniles reach maturity before autumn, overwinter and breed the following summer.

Terrestrial dipterous flies, especially *Fucellia maritima* and *Fucellia fucorum*, utilize the strand-line macroalgae for the deposition of their eggs. The flies favour the drier wrack beds, and three larval instars (stages between moults) are passed there prior to pupation. Larvae are not adapted to living in wet wrack owing to a lack of hairs on their posterior spiracles and large spines on the ventral surface which are present in other wrack flies. Emergence of adults is sudden towards the end of March and adults remain in abundance until the end of September (Egglishaw, 1960). In contrast to the larvae, adults are most attracted to wet wrack. Other flies, such as *Coelopa frigida*, *Coelopa pilipes* and *Thoracochaeta zosterae* breed in the wrack beds and would not be found on the shore but for the accumulations of wrack in which to live and breed (Eltringham, 1971).

Some beetles and centipedes also complete their reproductive cycle in the wrack beds. The staphylinid beetle, *Bleduis spectabilis* burrows in the sand, its tunnels have a side chamber in which the larvae develop. Parents supply the larvae with food and ventilate the burrow. The centipede *Hydoschendyla submarina* has become wholly adapted to life in the littoral zone. The female lays eggs that are impermeable, and so are not affected osmotically if inundated by seawater (Eltringham, 1971).

Resilience assessment. The driftline is a transient feature , consequently in order to utilize the resources that the stranded debris provides, the community reaches maturity within a few weeks. Such rapid colonization is achievable owing to the fact that species of the community originate from both terrestrial (e.g. flies, centipedes and beetles) and marine (e.g. sand hoppers) environments so can migrate quickly from adjacent habitats.

If a remnant population of young adults survived to breed of the key characterizing talitrid , recovery would begin within a year. However, if a population were to be entirely removed, recovery would take much longer and be reliant on the recolonization of adults able to breed. However, the ability of amphipods to colonize over wider areas may be restricted by their endogenous pattern of activity that generally restricts movement over a relatively short distance in the intertidal zone (see Bregazzi & Naylor, 1972; Lincoln, 1979; Scapini *et al*., 1992). Talitrids may be transported within the water column allowing recolonization between populations or may raft on drift algae (Brooks & Bell, 2001) supporting recolonization of depopulated habitats. Based on the available information resilience is assessed as 'High', for any level of impact (resistance is 'None', 'Low', 'Medium' or 'High'.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: 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 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 important characterizing species of the strand-line, *Talitrus saltator*, occurs to the south of the UK and is widely distributed around European and Mediterranean coasts, so is likely to be tolerant of a chronic temperature increase of 2°C. Bregazzi & Naylor (1972) observed that the timing of activity was temporarily advanced by increased temperature but otherwise the activity pattern possessed a large measure of temperature independence. Specimens brought in to laboratory conditions from a field temperature of 10.5°C were introduced to (within 3 hours) and maintained for 15 days at constant temperatures of 15, 20 and 25°C. *Talitrus saltator* maintained at the highest temperatures the activity mid-point advanced by as much as three hours to occur before midnight. However, alterations in activity were compensated for within two to ten days. Acute temperature increases may therefore temporarily disrupt activity of the sand hopper and other similar species, but owing to insufficient evidence for adverse effects in the field intolerance has been assessed to be low. Immediate recovery has been recorded as the locomotor activity rhythm is synchronized within a few days. As temperatures increase talitrids and other invertebrates may be able to burrow deeper within the wrack or within the underlying sediments to escape desiccation and increased temperatures. Williams (1983b) found that burrow depth in *Talitrus saltator* is linked to moisture content and optimal humidity levels. Talitrids undertake seasonal migrations up and down the shore to avoid stressful conditions and to regulate temperature, desiccation and inundation (Williams, 1995), these behavioural responses may mean that the population migrates or changes position within the sediment in response to changes in temperature but survives.

Changes in temperature may indirectly affect this biotope by altering the supply of macroalgae and//or by altering the nutritive quality of the macroalgae (Rodil *et al*., 2015).

Sensitivity assessment. Based on distribution and laboratory experiments the key characterizing talitrids are considered able to tolerant either a chronic or acute increase in temperature at the benchmark. This biotope is found at the upper shore and is likely to experience wide temperature fluctuations during the tidal cycle (although it will not be inundated with every tide). Acute temperature increases (5°C for one month) may exceed tolerances of the associated invertebrates in the summer months or in the winter a sudden increase in temperature may also affect cold acclimated individuals. Exposure to warmer waters during the tidal cycle will, however, be brief and talitrids may burrow either downwards within sediments or migrate up the shore to avoid unfavourable conditions. Resistance to both an acute and chronic increase in temperature (2°C for one year) is therefore assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

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

The important characterizing species of the strand-line, *Talitrus saltator*, remains inactive in high shore burrows for much of the winter in more northern latitudes. In the laboratory, exposure to low temperature (2 or 3°C) was accompanied by the onset of inactivity, a precipitous decrease in oxygen uptake and a marked increase in the concentrations of the major ions in the haemolymph (Spicer *et al*., 1994). In addition to causing a complete cessation of activity, chilling (2-3°C for 8 hours) also causes a delay in the successive activity peaks following return to normal temperatures. Maximum delay occurred if chilling began during the inactive period of the sand hopper and was of equal duration to that of the chill. At other times the delay was less than that of the chill (Bregazzi, 1972). Therefore, it is possible that exposure to decreased temperatures in the field would enforce a period of inactivity causing disruption to the species normal behaviour with potential consequences for the maintenance of a position with appropriate moisture, e.g. the substratum may become too dry or the temporary burrow become inundated with water. The effects of an unusually cold winter are likely to be a simple physical one, whereby quiescent sand hoppers freeze within the substratum, causing cell and tissue damage and eventually rupture of cell and body walls. Other supralittoral members of the Talitridae with a similar habit to *Talitrus saltator* were reported to be adversely affected by the severe winter of 1962/63. In particular, sand hoppers of the genus *Orchestia* were found dead in considerable numbers (Crisp, 1964). Talitrids undertake seasonal migrations up and down the shore to avoid stressful conditions and to regulate temperature, desiccation and inundation (Williams, 1995), these behavioural responses may mean that the population migrates or changes position within the sediment in response to changes in temperature but survives.

Sensitivity assessment. Resistance has been assessed as 'Medium' as the behaviour of the sand hopper is likely to be disrupted by mild chilling, whilst death as a result of freezing is probable only in severe winters. Recovery from mild chilling has been assessed to be immediate following an initial disruption to its activity. Resilience is therefore assessed as 'High' and sensitivity is 'Low'.

	Resistance	Resilience	Sensitivity
Salinity increase (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

This biotope occurs in full (30-35 ppt) and variable (18-35 ppt) salinity (JNCC, 2015). Biotope examples occurring in variable salinity are likely to withstand a change to full salinity as this clearly falls within the range of species tolerances. For biotopes that occur in full salinity the sensitivity assessment considers an increase to hypersaslinity >40 ppt.

Calosi *et al*. (2007) assessed the effects of short-term exposure on heart rate (a measure of stress) for *Talitrus saltator* and also assessed long-term survival following continuous submergence in a range of salinities from 0-66. The test individuals were collected from Italian and French beaches. The lowest salinity tested (salinity 0) stressed the amphipods more than the highest . Half of the tested individuals exposed to salinity 66 had survived more than 200 hours (the end of the test based on 50% mortality.

Other experiments have shown that changes in salt concentration can affect orientation and locomotion in the characterizing amphipod *Talitrus saltator*, however the effects are reversible within a few hours (Ugolini *et al*., 2015).

Sensitivity assessment. As this biotope occurs on the upper shore, periods of tidal inundation are brief and the specie present are likely to be able to move away from, or tolerate, short-term increases in salinity (as experienced during periods of high evaporation). The experiments by Calosi *et al.* (2007) indicate that *Talitrus saltator* can tolerate short periods of exposure to high salinities and that individuals can survive periods of salinity much greater than the pressure benchmark for many hours. This biotope is therefore considered to have 'High' resistance to this pressure, high resilience (by default), so that the biotope is assessed as 'Not sensitive'. Changes in salinity may, however, have indirect effects on this biotope if the supply of macroalgae from adjacent areas is affected by increased salinities.

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

This biotope occurs in full (30-35 ppt) and variable (18-35 ppt) salinity (JNCC, 2015). Biotope examples occurring in full salinity are likely to withstand a change to variable salinity as this clearly falls within the range of species tolerances. For biotopes that occur in variable salinity the sensitivity assessment considers an increase to low salinity <18 ppt. The lack of records from low salinity may be due to the habitat occurrence as sand beaches tend to occur in the coast and lower reaches of estuaries, rather than in more sheltered areas with riverine inputs and lower salinity. The community may experience periods of freshwater inundation owing to episodes of rain so that species present are likely to be able to tolerate short-term exposure to lower salinities. The highly mobile adult forms of wrack flies are likely to go elsewhere, whilst sand hoppers such as *Talitrus saltator* and other strand-line fauna are likely to seek protection within the strand-line debris.

Calosi *et al.* (2007) assessed the effects of short-term exposure on heart rate (a measure of stress) for *Talitrus saltator* and also assessed long-term survival following continuous submergence in salinities of 0, 5.5 and 11. The test individuals were collected from Italian and French beaches. The lowest salinities tested stressed the amphipods with the highest mean heart rate values recorded at salinity 0 at 1 and 4 hours, while heart rate was lowest in salinities of 11 and 33. Half of the tested individuals exposed to salinity 0 died within 5 hours. Individuals exposed to 5.5 and 11 salinity showed much higher long-term survival, with 50% mortality occurring at 400 h and approximately 330 hours, respectively (Calosi *et al.*, 2007).

Other experiments have shown that changes in salt concentration can affect orientation and locomotion in the characterizing amphipod *Talitrus saltator*, however the effects are reversible within a few hours (Ugolini *et al.*, 2015).

Sensitivity assessment. As this biotope occurs on the upper shore, periods of tidal inundation are brief and the specie present are likely to be able to move away from, or tolerate, short-term decreases in salinity (as experienced during periods of high rainfall). The experiments by Calosi *et al.* (2007) indicate that *Talitrus saltator* can tolerate short periods of exposure to freshwater and can survive periods of salinity lower than the pressure benchmark for many hours. This biotope is therefore considered to have 'High' resistance to this pressure, high resilience (by default), so that the biotope is assessed as 'Not sensitive'. Changes in salinity may, however, have indirect effects on this biotope if the supply of macroalgae from adjacent areas is affected by lowered salinities.

Water flow (tidal current) changes (local)	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 community is unlikely to be affected by an increase in water flow rate, as the habitat is created by the deposition of macroalgae and other organic debris on the ebb tide. This pressure is therefore considered to be 'Not relevant'. Change s in local hydrodynamics that altered the supply of macroalgal debris would affect this biotope but this is not assessed at the pressure benchmark.

Emergence regime changes	None Q: Low A: NR C: NR	High Q: High A: Low C: High	Medium Q: Low A: Low C: Low

As the biotope is defined by the height of the tide it is sensitive to changes in tidal emergence, within the footprint of the impact. An increase or decrease in tidal heights will alter the position of the biotope on the shore. Within the footprint of the impact, resistance is 'None' and recovery is 'High', so that sensitivity is assessed as 'Medium'. However, the location of the biotope not its presence on the shore would change: unless prevented by vertical hard structures or other barriers, the biotope would rapidly reform (within days) at a new position.

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

The community is unlikely to be affected by change in wave action, as the habitat is created by the deposition of macroalgae and other organic debris on the ebb tide. Changes in wave height that altered the height of the tidal range may, however, alter the position of the biotope and result in it forming higher or lower on the shore.

Storm wave erosion is likely to be an important factor in determining the quantity and quality of strand-line debris deposited on the beach. Increased wave exposure onshore is likely to increase the quantity of debris washed-up and available for colonization by strand-line fauna. For example, Shackley & Llewellyn (1994) recorded a positive correlation between strand-line debris weight and total amphipod numbers at beaches in South Wales.

Sensitivity assessment. A change in wave height at the pressure benchmark is not considered to significantly impact this biotope. Resistance is therefore assessed as 'High' and resilience as 'High' so that the biotope is considered to be 'Not sensitive'.

Chemical Pressures

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

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

Contamination at levels exceeding the pressure benchmark may have negative effects. *Talitrus saltator* has been used as a spatial and temporal heavy metal biomonitor (Rainbow *et al.*, 1989, 1998; Fialkowski *et al.*, 2000). Bioavailable sources of trace metals to talitrids are available in solution and in food, the latter consisting of decaying macrophytic material on the strand-line. Such material acts as an adsorption site for heavy metals locally, as sandy substrata does not adsorb contaminants as easily as other substrata. The species is an efficient bioaccumulator of heavy metals whose moult cycle does not interfere with its biomonitoring potential. Specimens of the sand hopper from the Isle of Cumbrae, a non metal polluted site in the Clyde, Scotland, had zinc concentrations between 145-181 µg /Zn/g and copper concentrations of 35.8 µg/Cu/g (Rainbow & Moore, 1990). In comparison, *Talitrus saltator* from a heavy metal polluted site in Dulas Bay, Anglesey, Wales (Foster *et al.*, 1978; Boult *et al.*, 1994) had a zinc concentration of 306 µ g/Zn/g and a copper concentration of 112 µg/Cu/g. In the Gulf of Gdansk, Poland, comparable concentrations for zinc were in the region of 200-400µ g/Zn/g with bottom sediment zinc concentrations of 0-20 µg/g and 40µ g/g in the most polluted areas (Fialkowski *et al.*, 2000). It is likely that the most significant contamination pathway to the amphipod is that of pollutants adsorbed to vegetative matter that is consumed rather than that concentrated in the water column.

Ugolini *et al.* (2012) investigated behavioural responses (locomotor activity and substrate selection) of the amphipod *Talitrus saltator* after laboratory exposure to different concentrations of Hg, Cu and Cd. Locomotor activity, measured with a microwave radar device, was assessed in animals exposed to contaminated sand and in sandhoppers previously kept for 48 h in contaminated seawater and tested in clean sand. Tests in contaminated sand showed that sandhopper locomotor activity varied in a dose-dependent manner in the presence of Cu and Hg (at lower Hg concentration they were more active during daytime) but did not show significant changes in Cd-exposed animals except for disappearance of the typical circadian activity pattern. Pre-exposure to trace metals in seawater induced a significant decrease of movements for all metals, although the effects varied according to the toxicity of the metal.

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.

Contamination at levels exceeding the pressure benchmark may have negative effects. Supralittoral sediment habitats immediately adjacent to the littoral zone can be susceptible to damage from oil pollution and any subsequent attempts to remove the oil by scraping off the sediment surface. Oil which reaches the shore following a pollution incident generally gets concentrated along the high tide mark. Oil deposits on the strand-line and amongst seaweed would probably incapacitate and kill, by smothering and toxic effects, a considerable proportion of invertebrates that are found in strand-line debris. For instance, following the *Torrey Canyon* oil tanker spill in 1967 quantities of *Talitrus saltator* were found dead at Sennen, Cornwall, as were other scavengers of the strand-line, e.g. *Ligia* and *Orchestia*. Signs of oil dispersant detergent damage were reported at Constantine Bay (Cornwall) where sand hoppers were found in a lethargic state at the base of dunes after spraying with detergent (Smith, 1968).

Shackley & Llewellyn (1997) monitored shores with dune systems at Pendine and Pembury within Carmarthen Bay, that received oil spilt by the *Sea Empress* tanker in February 1996. Strand-line material at the two beaches contained quantities of oiled material and small particles of oil (2-5 mm in diameter) became mixed in with the sediment. However, Pendine was amongst the initial areas to become contaminated and received more viscous oil than Pembury, where oil appeared later and in a more weathered form. Tar balls persisted within the sediment at Pendine a year after the spill, whilst very little oiled material was found at Pembury a year later. Whilst physical and biological factors are important in determining the amphipod populations on such shores and differ between localities, differences were found in the abundance of amphipods between the two shores that could not be accounted for by physical and biological processes alone. Shackley & Llewellyn (1997) suspected that the persistence of oil at the strand-line and in the sediment beneath was affecting the strand-line community. Oil amongst strand-line material and in the sediment may affect the viability of species and/or it may simply deter species from colonizing. Recovery of the community is likely to vary according to the extent of oil pollution. Oil may be responsible for the decimation of amphipod populations, unless a remnant population survives buried in the substratum or in refuges higher than the tide mark. Some species in particular would be at risk. Amphipods, such as *Talitrus saltator* have an annual univoltine reproductive cycle (only one generation reaches maturity each year) (Williams, 1978). Newly hatched juveniles are unable to bury themselves in the sand to avoid desiccation and remain in amongst the freshly deposited strand-line debris, which maintains an 85-90% relative humidity over low tide (Williamson, 1951), so oil pollution could effectively remove the breeding population and recovery consequently protracted. Terrestrial species including coleopteran insects and dipteran flies are likely to colonize the strand-line rapidly following the deterioration of oil.

The exposed sandy beach of Ladeira (Corrubedo Bay, NW Spain) was sampled during seven years (2003-2009) after the Prestige oil spill (winter 2002-03), to determine interannual variations in the macroinfaunal community (Junoy *et al*., 2013). The amphipods *Talitrus saltator* and *Talorchestia deshayesii* dominated from the drift line upwards. Multivariate analysis showed that the Prestige oil spill scarcely affected the macroinfaunal community structure during the study period (2003-2009) and its effect was limited just to the first campaign (2003), six months after the Prestige accident (Junoy *et al*., 2013).

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

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

Contamination at levels exceeding the pressure benchmark may have negative effects. In general, crustaceans are widely reported to be intolerant to synthetic chemicals (Cole *et al*., 1999) and intolerance to some specific chemicals has been observed in amphipods. Amphipods have been reported to be intolerant to TBT and leachates from antifouling paints (Laughlin *et al*., 1982). Numbers of the sand hopper, *Talitrus saltator*, were found in a lethargic state at the base of dunes at Constantine Bay (Cornwall), after spraying with the BP1002 an oil dispersant detergent after the *Torrey Canyon* oil spill (Smith, 1968).

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

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	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 strand-line habitat is created as the tide ebbs and deposits organic debris on the shore. Species inhabiting the strand-line are either fully terrestrial, or are marine species that have assumed a terrestrial mode of life, and all can therefore respire in air. Tidal inundation is brief and will not occur at every tide so exposure to de-oxygenated waters would be limited and mobile species could avoid exposure. This pressure is therefore considered 'Not relevant'.

Nutrient enrichment	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 community is unlikely to be directly affected by an increase in the concentration of dissolved nutrients in the water column, as the food resource that the community utilizes is in the form of macroalgal debris. This pressure is therefore considered 'Not relevant'. Changes in nutrient status that alter the supply of macroalgae from adjacent habitats could alter the quality of this habitat but this is not assessed. The benchmarkl is protective and it is unlikely that supply of fucoids, keklps and red algae would be imnpacted although the supply of ephemeral green algae, where there were previously blooms, may change.

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

The lack of in-situ primary production means beach assemblages are dependent on the import of organic material in the form of macroalgae debris, other organic materials and particulate and dissolved organic matter. An input of organic matter at the pressure benchmark may be consumed by the amphipods and fly larvae or broken down by bacteria and consumed by meiofauna. At the benchmark level the input of organic matter is likely to represent a food subsidy that enhances secondary production. Biotope resistance is therefore assessed as 'High' and resilience as 'High' so that the biotope is considered to be 'Not sensitive'.

Physical Pressures

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

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is, therefore 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

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

The biotope is characterized by the sedimentary habitat (JNCC, 2015), a change to an artificial or rock substratum (such as flood defence structures) would alter the character of the biotope leading to reclassification. Although wrack may still accumulate the sedimentary community would be lost, where sea defences are put in place this typically leads to squeeze and a reduction in the size of the beach, wave reflection from structures, rather than dissipation through sediments may also lead to a reduction in deposited algae. These changes have been observed to result in loss or reduction of drift lines (Dugan *et al*., 2008).

Sensitivity assessment. Based on the loss of the biotope, resistance is assessed as 'None', recovery is assessed as 'Very low' (as the change at the pressure benchmark is permanent and sensitivity is assessed as 'High'.

Physical change (to another sediment type)	Low Q: Low A: NR C: NR	Very Low Q: Low A: NR C: NR	High Q: Low A: Low C: Low

The presence of the drift line is the key feature defining the biotope and is largely independent of the underlying sediment, although draft lines are typically a feature of coarse sediment shores rather than mudflats. However, physical changes to the underlying sediment could result in changes to the sedimentary community and the presence of suitable habitat for the talitrids which burrow into the sediment during the day. A change in particle size could alter sediment penetrability and the degree to which burrows can be maintained. The underlying sediment will also determine factors such as drainage and water content. changes in wave dissipation (increase or decrease) could alter the accumulation of macroalgae which in turn could alter the biological assemblage through changes in drift line biomass and depth, changes in habitat suitability, food supply and decomposition rates.

Sensitivity assessment. Changes to the underlying sediment could alter drift line size and position and alter habitat suitability for the characterizing talitrid amphipods. Biotope resistance is assessed as 'Low' based on the drift line habitat and talitrids. As the change at the pressure, benchmark is permanent, resilience is assessed as 'Very low' and sensitivity is assessed as 'High'.

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

Removal of the deposited macroalgae and other organic debris and the underlying substratum would cause a loss of habitat for the strand-line community. Species utilizing the stranded material are likely to be removed along with the material and the habitat would be destroyed.

The benchmark against which resistance is assessed assumes **a single event**, so following deposition of fresh macroalgae, recovery of the community would be expected to be very rapid in terms of the species present (e.g. many species would migrate to the strand-line from the terrestrial habitats and sand hoppers would be buried in the substratum awaiting the arrival of a new strand-line) but may not attain their former abundance for several months as a considerable proportion of characterizing species would be lost. However, **repeated removal of the substratum within a short space of time**, e.g. as a result of mechanical raking for the purposes of beach cleaning, would be expected to impact upon the recovery of the strand-line community. A proportion of the population (e.g. sand hoppers, beetles, mites, flies etc.) would be removed or disturbed each time, including important juvenile stages, so that recovery would have to occur from a diminishing population and may take a considerable period of time from the point that the activity ceased. Some species, in particular, would be at risk. Amphipods, such as *Talitrus saltator* have an annual univoltine reproductive cycle (only one generation reaches maturity each year) (Williams, 1978). Newly hatched juveniles are unable to bury themselves in the sand to avoid desiccation and remain in amongst the freshly deposited strand-line debris, which maintains an 85-90% relative humidity over low tide (Williamson, 1951). The continuous removal of strand-line algae, even over the summer months will in the long-term, effectively remove the population (Llewellyn & Shackley, 1996).

Surveys of selected taxa across 60 sites in Scotland (Gilburn, 2012) found that cleaned beaches contained reduced taxon richness (of the eight selected macroinvertebrate taxa, including amphipods). Where the entire beach was groomed, taxon richness was lowest and talitrids were absent, these were, however, present on beaches where there were ungroomed sections (Gilburn, 2012), indicating the importance of refugia from disturbance to maintain populations of talitrid amphipods (see also Fanini *et al*., 2005).

Sensitivity assessment. Resistance to a single event of extraction, is assessed as 'None' as the drift line habitat would be removed, resilience is assessed as 'High' and sensitivity is, therefore, assessed as 'Medium'.

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

This biotope is subject to physical disturbance due to the rising and falling of the tide, wave action, and the movement of marine debris, including strand line material. Human trampling, and in this specific case, mechanical beach cleaning/raking, are potential sources of additional abrasion and physical disturbance. Adults of the many terrestrial species that exploit the biotope are highly mobile, e.g. wrack flies, and are likely to avoid disturbance.

Changes in abundance of talitrid amphipods on urban beaches subject to high levels of recreational use (leading to abrasion pressures) were observed by Bessa *et al.* (2014), this study compared abundances between samples taken ten years apart and thus the trends observed were not directly attributable to trampling vs beach cleaning or other pressures although they illustrate a general trend in density patterns as recreational use increases. Ugolini *et al.* (2008) carried out a controlled trampling experiment on *Talitrus saltator*. Plastic cylinders of 110 cm diameter (area 0.95 m^2) were placed in the sand and all individuals trapped and counted, and 400 steps were made in a cylinder in 15 minutes after the amphipods had reburied. The trampling rate was based on an observed number of beach users and therefore represents a realistic level of exposure. Alive sandhoppers were counted at the end of the experiment and 24 hours after. Trampling significantly reduced the abundance of the amphipods and after 24 hours the percentage of surviving amphipods dropped to almost zero, while survival rates of control (untrampled) amphipods were unaffected. Abrasion and compaction can, therefore, kill buried amphipods within sediments.

Sensitivity assessment. The trampling experiment (Ugolini *et al*., 2008) represents a high intensity of abrasion with multiple steps on the sediment within a short time period. The experiment does, however, demonstrate that amphipods are sensitive to abrasion and compaction of the sediment and these results are observed by comparisons between heavily and lightly used areas (Bessa *et al*., 2014). Resistance to a single abrasion event is therefore assessed as 'Low' based on the characterizing talitrids. Resilience is assessed as 'High', based on migration from adjacent populations and in-situ reproduction by surviving amphipods. Sensitivity is therefore assessed as 'Low'. This assessment may underestimate sensitivity to high levels of abrasion (repeated events within a short period).

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

Llewellyn and Shackley (1996) found that mechanical beach cleaning had a serious deleterious effect on strandline related species diversity and population abundance. When not subjected to cleaning a fully balanced, representative selection of strandline invertebrates was present, where mechanical cleaning had occurred, there was a very poor selection of strandline invertebrates. When material was left on the beach for 5 months, amphipods and other associated strandline fauna appeared to recover (Llewellyn & Shackley, 1996).

Gheskiere *et al*. (2006), tested the effects of experimental mechanical beach cleaning on meiofauna within the strandline at De Panne (western Belgian coast). The beach consists of fine sands and the strandline was natural and had not been cleaned before. The beach cleaner removes algae and wrack and scrapes up the upper sand layer to 5cm depth. Cleaning caused an immediate decrease in density and changes in the biological assemblage. Although differences between control and cleaned plots were evidence at 4 and 9 hours , populations had recovered following the next tide and it was assumed that this occurred via vertical migration from deeper sediments (Gheskiere *et al*., 2006). One-off cleaning may, therefore, have little effect on meiofauna but chronic exposure may lead to progressive population depletion.

The evidence assessed for the abrasion pressure is also considered relevant to this pressure (see above).

Sensitivity assessments. Abrasion combined with penetration and disturbance of sediments is likely to disturb and damage the drift line and the associated assemblage. Displacement of the strandline may lead to some mortality of species living within, although the highly mobile flies are likely to escape. Talitrids in the drift line or buried within sediments are likely to be damaged and other species may be disturbed. Biotope resistance is assessed as 'Low' and resilience is assessed as 'High', so that sensitivity is assessed as 'Low'.

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

The community is unlikely to be affected by an increase or decrease in the concentration of suspended solids in the water column, as the habitat is created by the deposition of macroalgae and other organic debris on the ebb tide.

Sensitivity assessment. This biotope occurs high on the shore at the limit of tidal inundation, any exposure to increased or decreased suspended solids is limited to short periods. The characterizing species are unlikely to be impacted; a decrease in suspended organic matter and solids would reduce the supply of material to this biotope but as long as the deposition of drifting macroalgae was unaffected this is unlikely to lead to changes in the biotope. Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

Smothering and siltation rate changes (light)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Many of the species inhabiting the biotope are highly mobile adult forms, e.g. wrack flies,that would avoid being physically covered by additional sediment. A deposit of 5 cm of sediment would bury the strand-line material and the species active within it. The habitat would be temporarily lost to those species, mainly terrestrial, that were able to move away. Adult sand hoppers, such as *Talitrus saltator*, are likely to be capable of burrowing through additional sediment, as the species are capable of burrowing to depths between 10-30 cm (Williams, 1983b). Newly hatched juveniles are unable to bury themselves in the sand to avoid desiccation and remain in amongst the freshly deposited strand-line debris, which maintains an 85-90% relative humidity over low tide (Williamson, 1951). Although juveniles may not be able to bury through the additional sediment to regain the surface and fresh deposits of macroalgal debris, it is likely that the seaweed debris would itself maintain a sufficiently open structure under the sediment for vulnerable juvenile stages to survive.

Sensitivity assessment. Resistance has been assessed as 'High' as most species would be expected to survive a single event at the pressure benchmark. Any changes would be short-lived in this biotope which is typically subject to high levels of natural spatial and temporal variation depending on tidal heights, wave action from storms and the supply of macroalgae. Recoverability, in terms of the species present and abundance, has been assessed to be 'High' (within a few days) as characterizing species would either remain in situ or are sufficiently mobile to rapidly return, e.g. flies. The biotope is therefore considered to be 'Not sensitive' to this pressure.

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

A deposit of 30 cm of fine sediment is likely to completely bury the drift line and fill the interstitial places between the wrack, preventing feeding and respiration and leading to smothering. As the drift line is found on the upper shore where the tide begins to ebb, water movements may not be great enough to rapidly remove the deposit and it may remain in-situ for some time. Fly larvae, beetle eggs and other associated invertebrates are likely to die. No evidence was found for burrowing ability of talitrids through fine deposits. Maurer *et al*. (1981) found that the amphipod *Parahaustorius longimerus* which occurs intertidally in clean, well-sorted sands and is an active, effective burrower was able to regain the surface after being buried by sand far more easily than when buried under silt/clay mixtures. it is, therefore, possible that talitrids have limited ability to burrow through a thick deposit of fine sediment.

Sensitivity assessment. Biotope resistance to this pressure is assessed as 'None' as a deposit at the pressure benchmark may completely cover the strandline, removal of the deposit and deposition of new algal material will support the recovery of a drift line habitat. Resilience is assessed as 'High' as a new drift line community is likely to be present within two years. Biotope 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

Not assessed. The presence of large plastic debris could create artificial drift lines that do not provide food or breakdown easily. Amphipods may also consume microplastics although no negative effects have been documented. Ugolini *et al*. (2013) found that *Talitrus saltator* could consume polyethylene microspheres (diameter 10-45 mu m). Most microspheres were expelled in 24 hr and were totally expelled in one week. Microsphere ingestion on the survival capacity in the laboratory. Analyses carried out on faeces of freshly collected individuals revealed the presence of polyethylene and polypropylene, confirming that microplastic debris could be swallowed by *Talitrus saltator* in natural conditions.

The talitrid *Orchestia gammarellus* has also been recorded as ingesting microplastics in the size range 20-200 µm (Thompson *et al*., 2004).

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found to support an assessment for the biotope. For some amphipods, there is evidence for geomagnetic orientation being inhibited or disrupted by the presence of electromagnetic fields or by changing magnetic fields. Arendse & Barendregt (1981) manipulated magnetic fields to alter the orientation of the talitrid amphipod *Orchestia cavimana*.

Deep-water amphipods *Gondogenia arctica* have been shown to be sensitive to even weak electromagnetic fields which cancel magnetic orientation (Tomanova & Vacha, 2016). Loss of orientation was observed at a radiofrequency electromagnetic field of 2 nT (0.002 µT) (Tomanova & Vacha, 2016).

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

Not relevant.

Introduction of light or shading	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

This biotope is characterized by macroalgal debris cast up on the beach and not by living primary producers, changes in light level would therefore not alter the character of the biotope, as the drift-line is free draining there will be few diatoms unlike lower parts of the shore and hence no effects on primary production will occur from changes in light levels that will alter the character of the biotope.

Changes in light level may, however, affect activity rhythms of the invertebrates. Amphipods within the biotope prefer shade and therefore an increase in light may inhibit activity, particularly at night when they emerge from the sediment and are most active (Jelassi *et al*., 2015; Ayari *et al*., 2015). Hartwick (1976) found that artificial lighting interfered with learning or orientation cues by Talitrids.

Orientation by light has been well studied for intertidal amphipods (particularly *Talitrus saltator)*. Intertidal amphipods orientate themselves by a range of factors that include (but are not limited to) visual cues based on solar or astronomic cues and the geomagnetic field (Scapini, 2014). Activity patterns are also linked to internal biological clocks that respond to diel, tidal, lunar and seasonal cycles so that animals are active during the most suitable time of day or night (Scapini, 2014). The introduction of light or an increase in shading could, therefore, alter behavioural patterns and navigation. As responses may be species specific or vary according to local factors or individual needs such as feeding, mating, it is not possible to provide a simple assessment for this species. Some sensitivity is, however, likely if incident light levels were altered. This will depend, however, on the footprint and intensity of impact. Fanini *et al*. (2014) found no difference in abundance of *Talitrus saltator* between Greek beaches that frequently hosts small-scale beach parties with lights at night and those that were not used in this way. However, the available evidence was not adequate to make a assessment of sensitivity.

Barrier to species movement	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Many of the invertebrate fauna that inhabit the drift line, such as flies, beetles and centipedes are terrestrial in origin and do not disperse in the water column so this pressure is not relevant to these species. As the amphipods that characterize this biotope have benthic dispersal strategies (via brooding), water transport is not a key method of dispersal over wide distances, as it is for some marine invertebrates that produce pelagic larvae. The biotope (based on the biological assemblage) is, therefore, considered to have 'High' resistance to the presence of barriers that lead to a reduction in tidal excursion, resilience is assessed as 'High' (by default) and the biotope is 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	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The invertebrate fauna of the biotope possess visual acuity and are able to detect changes in light for purposes of navigation and probably are able to detect prey items within their visual envelope. However, apart from flies which would be temporarily disturbed by the approach of machinery, other important characterizing species of the biotope are unlikely to be disturbed by visual presence. Some species of bird that frequent the biotope to feed are likely to be disturbed by the visual presence of machinery and people in the vicinity of the strand-line, and their feeding efficiency reduced, although this would benefit invertebrate species.

Sensitivity assessment. Biotope resistance is assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope group.

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

The driftline biotope is relatively transient and the underlying sediments are coarse, mobile and free-draining and low in organic matter. The biotope is exposed to air for much of the time and tidal inundation is limited. These factors limit establishment of marine and coastal invasive non-indigenous species as the habitat conditions are unsuitable for most species (Defeo *et al*., 2009). Sand sediments were considered to have greater resistance to invasive species than the muddy sediments typical of more sheltered shores, due to greater sediment instability and consequent habitat unsuitability. Although not directly colonising invasive macroalgae species including *Undaria pinitifada* and *Sargassum muticum* have been reported to change the biomass and composition of the strandline with potential trophic effects on consumers (Defeo *et al*. 2009 and references therein. Rossi *et al*. (2010) assessed the role of the invasive non-indigenous algae *Sargassum muticum* as a food source for amphipods using stable isotopes as markers. *Sargassum muticum* seemed to be one of the main food sources for the amphipod *Talitrus saltator* and, to a less extent, for the isopod *Tylos europaeus*. The importance of *Sargassum muticum* was however temporally variable and decreased during spring (in March and May), probably due to the availability of native macrophytes (Rossi *et al*., 2010).

Sensitivity assessment. No evidence was found that invasive non-indigenous species were directly affecting this biotope. Resistance was therefore assessed as 'High' and resilience as 'High', so that the biotope is assessed as 'Not sensitive'.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Amphipods may be infected by a number of parasites or pathogens that alter population numbers through changes in host condition, growth, behaviour and reproduction (Green Extabe & Ford, 2014). Infection by acanthocephalan larvae, for example, may alter behaviour and responses of gammarid amphipods (Bethel & Holmes, 1977). The amphipod *Orchestia gammarellus* is host to the parasitic protist *Marteilia* which has a feminizing effect on populations, with higher rations of females and intersex males in infected, estuarine populations (Ginsburger-Vogel & Desportes, 1979).

No evidence was found for pathogen/parasite outbreaks that may result in mass-mortalities in talitrid amphipods and this pressure is not assessed.

Removal of target species	None Q: High A: High C: High	High Q: High A: High C: High	Medium Q: High A: High C: High

Targeted removal of fresh deposits of algae may occur through commercial or recreational harvesting, on an intensive scale this would reduce the supply of material to the driftline. Driftlines and associated fauna may also be targeted for removal as part of beach cleaning (sometimes referred to as beach grooming) programmes. The physical damage arising from this activity is considered though the abrasion and penetration pressures. The driftline itself is likely to recover rapidly where seaweed is deposited on the beach although the removal of biomass may mean that subsequent drift lines decrease through the year as they are formed only of recently deposited material. The depth of a wrack bed is closely correlated with taxon richness (Gilburn, 2012), removal of driftlines allowing only a sparse bed to develop will therefore reduce biodiversity. Recent deposits are likely to contain talitrids but not the richer diversity observed in older, deeper beds (Gilburn, 2012).

Repeated grooming may also deplete the population of talitrids as these reproduce annually and the removal of the population will result in cumulative losses. The loss of amphipods from an area will reduce the food supply available to other invertebrates, birds and fish and the loss of the drift line can result in loss of feeding and nesting habitat for birds that utilise this habitat . Llewellyn & Shackley (1996) documented a 90% reduction in the abundance of two populations of birds that feed on macroinvertebrates as a result of beach cleaning.Studies in California have also shown that removal of macroalgae can reduce biodiversity of invertebrates and birds (Dugan *et al*., 2003).

Surveys of selected taxa across 60 sites in Scotland (Gilburn, 2012) found that cleaned beaches contained reduced taxon richness (of the eight selected macroinvertebrate taxa). Where the entire beach was groomed, taxon richness was lowest and talitrids were absent, these were however, present on beaches where there were ungroomed sections (Gilburn, 2012), indicating the importance of refugia from disturbance to maintain populations of talitrid amphipods (see also Fanini *et al*., 2005).

Sensitivity assessment. The sensitivity assessment considers the effects of removal of target species on the biotope rather than higher trophic levels (although the evidence section highlights these potential impacts). The loss of the driftline by targeted removal, either for fresh seaweed collection by commercial and recreational harvesters, or through beach cleaning will remove the driftline and lead to subsequent declines in material available to reform the biotopes. Resistance is therefore assessed as 'None'. Resilience is assessed as 'High' based on recovery of driftline and populations within two years (following cessation of the targeted removal). Biotope sensitivity is therefore assessed as 'Medium'.

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

The loss of the key characterizing species through unintentional removal would alter the character of the biotope. The ecosystem services such as secondary production and food for higher trophic levels such as birds and fish provided by the amphipods and other associated invertebrates would be lost.

Sensitivity assessment. Biotope resistance to loss of the characterizing species is assessed as 'Low' as the burrowing lifestyle and mobility of talitrids mean that a proportion of the population may escape removal. Resilience is assessed as 'High' based on in-situ recovery and migration from adjacent populations and sensitivity is therefore assessed as 'Low'

Bibliography

Arendse, M.C. & Barendregt, A., 1981. Magnetic orientation in the semi-terrestrial amphipod, *Orchestia cavimana*, and its interrelationship with photo-orientation and water loss. *Physiological Entomology*, **6** (4), 333-342.

Ayari, A., Jelassi, R., Ghemari, C. & Nasri-Ammar, K., 2015. Locomotor activity patterns of two sympatric species *Orchestia montagui* and *Orchestia gammarellus* (Crustacea, Amphipoda). *Biological Rhythm Research*, **46** (6), 863-871.

Backlund, H.O., 1945. Wrack fauna of Sweden and Finland: ecology and chorology. *Opuscula Entomologica* (Supplementum) **5**, 1-236.

Behbehani, M.I. & Croker, R.A., 1982. Ecology of beach wrack in northern New England with special reference to *Orchestia platensis*. *Estuarine, Coastal and Shelf Science*, **15** (6), 611-620.

Bessa, F., Goncalves, S.C., Franco, J.N., Andre, J.N., Cunha, P.P. & Marques, J.C., 2014. Temporal changes in macrofauna as response indicator to potential human pressures on sandy beaches. *Ecological Indicators*, **41**, 49-57.

Bethel, W.M. & Holmes, J.C., 1977. Increased vulnerability of amphipods to predation owing to altered behavior induced by larval acanthocephalans. *Canadian Journal of Zoology*, **55** (1), 110-115.

Boult, S., Collins, D.N., White, K.N. & Curtis, C.D., 1994. Metal transport in a stream polluted by acid mine drainage - the Afon Goch, Anglesey, U.K. *Environmental Pollution*, **84**, 279-284.

Bregazzi, P.K. & Naylor, E., 1972. The locomotor activity rhythm of *Talitrus saltator* (Montagu) (Crustacea, Amphipoda). *Journal of Experimental Biology*, **57**, 375-391.

Bregazzi, P.K., 1972. The effects of low temperature upon the locomotor activity rhythm of *Talitrus saltator* (Montagu) (Crustacea: Amphipoda). *Journal of Experimental Biology*, **57**, 393-399.

Brooks, R.A. & Bell, S.S., 2001. Mobile corridors in marine landscapes: enhancement of faunal exchange at seagrass/sand ecotones. *Journal of Experimental Marine Biology and Ecology*, **264** (1), 67-84.

Calosi, P., Morritt, D., Chelazzi, G. & Ugolini, A., 2007. Physiological capacity and environmental tolerance in two sandhopper species with contrasting geographical ranges: *Talitrus saltator* and *Talorchestia ugolinii*. *Marine Biology*, **151** (5), 1647-1655.

Chapman, V.J., 1976. *Coastal Vegetation*. Permagon Press.

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 441 pp., Swindon: Water Research Council on behalf of EN, SNH, CCW, JNCC, SAMS and EHS. [UK Marine SACs Project.], http://www.ukmarinesac.org.uk/

Connor, D.W., Brazier, D.P., Hill, T.O., & Northen, K.O., 1997b. Marine biotope classification for Britain and Ireland. Vol. 1. Littoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 229, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report No. 230, Version 97.06.

Cordaux, R., Michel-Salzat, A. & Bouchon, D., 2001. *Wolbachia* infection in crustaceans: novel hosts and potential routes of transmission. *Journal of Evolutionary Biology*, **14**, 237-243.

Cramp, S. & Simmons, 1983. *Handbook of the birds of Europe, the Middle East and North Africa. The birds of the Paleartic. Vol. III. Waders to Gulls.* Oxford University Press.

Cramp, S., 1988. *Handbook of the birds of Europe, the Middle East and North Africa. The birds of the western Paleartic. Vol. V. Tyrant flycatchers to thrushes.* Oxford University Press.

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.

Cummins, K.W., 1974. Structure and function of stream ecosystems. *Bioscience*, **24**, 631-641.

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.

Davidson, N.C., Laffoley, D., Doody, J.P., Way, L.S., Key, R., Drake, C.M., Pienkowski, M.W., Mitchell, M.R. & Duff, K.L., 1991. *Nature Conservation and Estuaries in Great Britain.* Peterborough: Nature Conservancy Council.

Davies, C.E. & Moss, D., 1998. European Union Nature Information System (EUNIS) Habitat Classification. *Report to European Topic Centre on Nature Conservation from the Institute of Terrestrial Ecology, Monks Wood, Cambridgeshire.* [Final draft with further revisions to marine habitats.], Brussels: European Environment Agency.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. & Scapini, F., 2009. Threats to sandy beach ecosystems: a review. *Estuarine, Coastal and Shelf Science*, **81** (1), 1-12.

Dugan, J.E., Hubbard, D.M., Rodil, I.F., Revell, D.L. & Schroeter, S., 2008. Ecological effects of coastal armoring on sandy beaches. *Marine Ecology*, **29**, 160-170.

Egglishaw, H.J., 1960. The life history of *Fucellia maritima* (Haliday) (Diptera, Muscidae). *Entomologist*, **93**, 225-231.

Eltringham, S.K., 1971. *Life in mud and sand*. London: The English Universities Press Ltd.

EnCams, 2002. Environmental Campaigns Seaside Awards. www.seasideawards.org.uk, 2002-08-06

Fanini, L., Cantarino, C.M. & Scapini, F., 2005. Relationships between the dynamics of two *Talitrus saltator* populations and the impacts of activities linked to tourism. *Oceanologia*, **47** (1).

Fanini, L., Marchetti, G.M., Baczewska, A., Sztybor, K. & Scapini, F., 2012. Behavioural adaptation to different salinities in the sandhopper *Talitrus saltator* (Crustacea: Amphipoda): Mediterranean vs Baltic populations. *Marine and Freshwater Research*, **63** (3), 275-281.

Fanini, L., Marchetti, G.M., Scapini, F. & Defeo, O., 2009. Effects of beach nourishment and groynes building on population and community descriptors of mobile arthropodofauna. *Ecological Indicators*, **9** (1), 167-178.

Fanini, L., Zampicinini, G. & Pafilis, E., 2014. Beach parties: a case study on recreational human use of the beach and its effects on mobile arthropod fauna. *Ethology Ecology & Evolution*, **26** (1), 69-79.

FEE, 2002. Foundation for Environmental Education, Blue Flag Awards. www.blueflag.org, 2002-08-06

Fialkowski, W., Rainbow, P.S., Fialkowska, E. & Smith, B.D., 2000. Biomonitoring of trace metals along the Baltic coast of Poland using the sand hopper *Talitrus saltator* (Montagu) (Crustacea, Amphipoda). *Ophelia*, **52**, 183-192.

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.

Fowles, A., 1994. *Invertebrates of Wales: a review of important sites and species. Invertebrates of Wales: a review of important sites and species.*, JNCC Peterborough.

Gheskiere, T., Magda, V., Greet, P. & Steven, D., 2006. Are strandline meiofaunal assemblages affected by a once-only mechanical beach cleaning? Experimental findings. *Marine Environmental Research*, **61** (3), 245-264.

Gilburn, A.S., 2012. Mechanical grooming and beach award status are associated with low strandline biodiversity in Scotland. *Estuarine, Coastal and Shelf Science*, **107**, 81-88.

Ginsburger-Vogel, T. & Desportes, I., 1979. Structure and biology of *Marteilia* sp. in the amphipod *Orchestia gammarellus*. *Marine Fisheries Review*, **41**, 3-7.

Green Etxabe, A. & Ford, A., 2014. Do demon shrimp carry demon parasites? *Freshwater Biological Association News*, **62**, 10-11.

Griffiths, C.L. & Stenton-Dozey, J., 1981. The fauna and rate of degradation of stranded kelp. *Estuarine, Coastal and Shelf Science*, **12**, 645-653.

Harrison, P.G., 1977. Decomposition of macrophyte detritus in seawater: effects of grazing by amphipods. *Oikos*, **28**, 165-170.

Hartwick, R., 1976. Beach orientation in talitrid amphipods: capacities and strategies. *Behavioral Ecology and Sociobiology*, **1** (4), 447-458.

Healy, B., 1979. Records of Enchytraeidae (Oligochaeta) Ireland. *Journal of Life Sciences, Royal Dublin Society*, **1**, 39-70.

Hurley, D.E., 1959. Notes on the ecology and environmental adaptations of the terrestrial Amphipoda. *Pacific Science*, **13**, 107-129.

Hurley, D.E., 1968. Transition from water to land in amphipod crustaceans. *American Zoologist*, **8**, 327-353.

Ignaciuk, R. & Lee, J.A., 1980. The germination of four annual strand-line species. *New Phytologist*, **84**, 581-591.

Jelassi, R., Bohli-Abderrazak, D., Ayari, A. & Nasri-Ammar, K., 2015. Endogenous activity rhythm in *Talitrus saltator*, *Britorchestia brito* (Crustacea, Amphipoda) and *Tylos europaeus* (Crustacea, Isopoda) from Barkoukech Beach (Tabarka, Tunisia). *Biological Rhythm Research*, **46** (6), 873-886.

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/

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database (MERMAID): Marine Nature Conservation Review Survey Database.* [on-line] http://www.jncc.gov.uk/mermaid

Junoy, J., Castellanos, C., Vieitez, J.M. & Riera, R., 2013. Seven years of macroinfauna monitoring at Ladeira beach (Corrubedo Bay, NW Spain) after the Prestige oil spill. *Oceanologia*, **55** (2), 393-407.

Junoy, J., Castellanos, C., Vieitez, J.M., de la Huz, M.R. & Lastra, M., 2005. The macroinfauna of the Galician sandy beaches (NW Spain) affected by the Prestige oil-spill. *Marine Pollution Bulletin*, **50** (5), 526-536.

Koop, K. & Griffiths, C.L., 1982. The relative significance of bacteria, meio- and macrofauna on an exposed sandy beach. *Marine Biology*, **66**, 295-300.

Koop, K. & Lucas, M.I., 1983. Carbon flow and nutrient regeneration from the decomposition of macrophyte debris in a sandy beach microcosm. In *Proceedings of the First international Symposium on Sandy Beaches, Port Elizabeth, South Africa, 17-21 January 1983. Sandy beaches as ecosystems*, (ed. A. McLachlan & T. Erasmus), pp. 249-262. The Hague, Dr W. Junk.

Koop, K., Newell, R.C. & Lucas, M.I., 1982. Microbial regeneration of nutrients from the decomposition of macrophyte debris on the shore. *Marine Ecology Progress Series*, **9**, 91-96.

Lack, P. (Ed.), 1986. *The atlas of wintering birds in Britain and Ireland.* T. & A.D. Poyser.

Laughlin, R., Linden, O. & Guard, H., 1982. Toxicity of tributyltins and leachates from antifouling paints on marine amphipods. , Karlskrona: Institutet for Vattenoch Luftvardsforskning.

Lincoln, R.J., 1979. *British Marine Amphipoda: Gammaridea.* London: British Museum (Natural History).

Llewellyn, P.J. & Shackley, S.E., 1996. The effects of mechanical beach-cleaning on invertebrate populations. *British Wildlife*, **7**, 147-155.

Maurer, D., Keck, R.T., Tinsman, J.C. & Leathem, W.A., 1981. Vertical migration and mortality of benthos in dredged material: Part

II—crustacea. *Marine Environmental Research*, **5** (4), 301-317.

McLachlan, A., 1983. Sandy beach ecology - a review. In *Sandy beaches as ecosystems* (ed. A. McLachlan & T. Erasmus), pp.321-381. The Hague: Dr W. Junk Publishers.

Morritt, D., 1988. Osmoregulation in littoral and terrestrial talitroidean amphipods (Crustacea) from Britain. *Journal of Experimental Marine Biology and Ecology*, **123**, 77-94.

Picton, B.E. & Costello, M.J., 1998. *BioMar* biotope viewer: a guide to marine habitats, fauna and flora of Britain and Ireland. [CD-ROM] *Environmental Sciences Unit, Trinity College, Dublin.*

Pienkowski, M.W., 1982. Diet and energy intake of grey and ringed plovers, *Pluvialis squatarola* and *Charadrius hiaticula*, in the non-breeding season. *Journal of Zoology*, **197**, 511-549.

Pugh, P.J.A., Llewllyn, P.J., Robinson, K. & Shackley, S.E., 1997. The association of phoretic mites (Acarina: Chelicerata) with sand-hoppers (Amphipoda: Crustacea) on the South Wales coast. *Journal of Zoology*, **243**, 305-318.

Rainbow, P.S. & Moore, P.G., 1990. Seasonal variation in copper and zinc concentrations in three talitrid amphipods (Crustacea). *Hydrobiologia*, **196**, 65-72.

Rainbow, P.S., Fialkowski, W. & Smith, B.D., 1998. The sand hopper *Talitrus saltator* as a trace metal biomonitor in the Gulf of Gdansk, Poland. *Marine Pollution Bulletin*, **36**, 193-200.

Rainbow, P.S., Moore, P.G. & Watson, D., 1989. Talitrid amphipods (Crustacea) as biomonitors for copper and zinc. *Estuarine, Coastal and Shelf Science*, **28**, 567-582.

Reyes-Martínez, M.J., Ruíz-Delgado, M.C., Sánchez-Moyano, J.E. & García-García, F.J., 2015. Response of intertidal sandy-beach macrofauna to human trampling: An urban vs. natural beach system approach. *Marine Environmental Research*, **103**, 36-45.

Robertson, A.I. & Mann, K.H., 1980. The role of amphipods in the initial fragmentation of eelgrass detritus in Nova Scotia, Canada. *Marine Biology*, **59**, 63-69.

Rodil, I.F., Lucena-Moya, P., Olabarria, C. & Arenas, F., 2015. Alteration of Macroalgal Subsidies by Climate-Associated tressors Affects Behavior of Wrack-Reliant Beach Consumers. *Ecosystems*, **18** (3), 428-440.

Rossi, F., Olabarria, C., Incera, M. & Garrido, J., 2010. The trophic significance of the invasive seaweed *Sargassum muticum* in sandy beaches. *Journal of Sea Research*, **63** (1), 52-61.

Salisbury, E., 1952. *Downs and dunes*. G. Bell & Sons.

Scapini, F., Chelazzi, L., Colombini, I. & Fallaci, M., 1992. Surface activity, zonations and migrations of *Talitrus saltator* on a Mediterranean beach. *Marine Biology*, **112**, 573-581.

Shackley, S.E. & Llewellyn, P.J., 1994. Factors affecting the invertebrate population abundance of the strand-line, the littoral fringe and supralittoral zones, of soft sediment beaches. , *Unpublished report, Countryside Council for Wales.*

Shackley, S.E. & Llewellyn, P.J., 1997. *Sediment shore impact assessment/monitoring: strandline fauna.* CCW Sea Empress Contract Science Report, 240., CCW Sea Empress Contract Science Report, 240.

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

Spicer, J.I., Morritt, D. & Taylor, A.C., 1994. Effect of low temperature on oxygen uptake and haemolymph ions in the sand hopper *Talitrus saltator* (Crustacea: Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **74**, 313-321.

Stenton-Dozey, J. & Griffiths, C.L., 1980. Growth, consumption and respiration by larvae of the kelp-fly *Fucellia capensis*. *South African Journal of Zoology*, **15**, 280-283.

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.

Tomanová, K. & Vácha, M., 2016. The magnetic orientation of the Antarctic amphipod *Gondogeneia antarctica* is cancelled by very weak radiofrequency fields. *Journal of Experimental Biology*, **219**, 1717-1724.

Ugolini, A., Cincinelli, A., Martellini, T. & Doumett, S., 2015. Salt concentration and solar orientation in two supralittoral sandhoppers: *Talitrus saltator* (Montagu) and *Talorchestia ugolinii* Bellan Santini and Ruffo. *Journal of Comparative Physiology a-Neuroethology Sensory Neural and Behavioral Physiology*, **201** (5), 455-460.

Ugolini, A., Pasquali, V., Baroni, D. & Ungherese, G., 2012. Behavioural responses of the supralittoral amphipod *Talitrus saltator* (Montagu) to trace metals contamination. *Ecotoxicology*, **21** (1), 139-147.

Ugolini, A., Ungherese, G., Ciofini, M., Lapucci, A. & Camaiti, M., 2013. Microplastic debris in sandhoppers. *Estuarine Coastal and Shelf Science*, **129**, 19-22.

Ugolini, A., Ungherese, G., Somigli, S., Galanti, G., Baroni, D., Borghini, F., Cipriani, N., Nebbiai, M., Passaponti, M. & Focardi, S., 2008. The amphipod *Talitrus saltator* as a bioindicator of human trampling on sandy beaches. *Marine Environmental Research*, **65** (4), 349-357.

Williams, J.A., 1995. Burrow-zone distribution of the supralittoral amphipod *Talitrus saltator* on Derbyhaven Beach, Isle of Man: a possible mechanism for regulating desiccation stress? *Journal of Crustacean Biology*, **15**: 466-475.

Williams, J.A., 1976. The effect of light on the locomotor activity and general biology of *Talitrus saltator* (Montagu). , Ph.D. thesis, Liverpool University, 258 pp.

Williams, J.A., 1978. The annual pattern of reproduction of *Talitrus saltator* (Crustacea: Amphipoda: Talitidae). *Journal of Zoology*, **184**, 231-244.

Williams, J.A., 1980. The light response rhythm and seasonal entrainment of the endogenous circadian locomotor of *Talitrus saltator* (Crustacea: Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **60**, 773-785.

Williams, J.A., 1983b. Environmental regulation of the burrow depth distribution of the sand-beach amphipod *Talitrus saltator*. *Estuarine, Coastal and Shelf Science*, **16**, 291-298.

Williamson, D.I., 1951. Studies in the biology of Talitridae (Crustacea, Amphipoda): effects of atmospheric humidity. *Journal of the Marine Biological Association of the United Kingdom*, **30**, 73-90.