



# MarLIN

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

### *Ophiura ophiura* on circalittoral muddy sand

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

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**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/1262>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

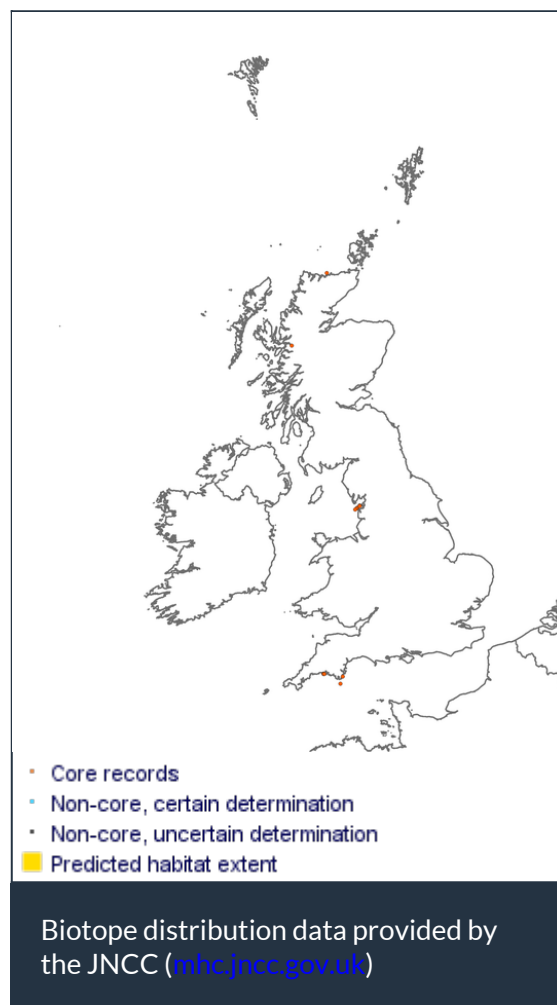
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**Refereed by** This information is not refereed

## Summary

### ☰ UK and Ireland classification

<b>EUNIS 2008</b>	A5.262TMP	None (TBC)
<b>JNCC 2022</b>	SS.SSa.CMuSa.Ooph	<i>Ophiura ophiura</i> on circalittoral muddy sand
<b>JNCC 2015</b>	None	None
<b>JNCC 2004</b>	None	None
<b>1997 Biotope</b>	None	None

### 🔍 Description

Circalittoral sandy mud and muddy sand characterized predominantly by epifaunal *Ophiura ophiura*. The description of this biotope is based on epifauna recorded from the Western Channel and the Celtic Sea, the Irish Sea, northern North Sea, southern North Sea, the Minches and western Scotland and the Scottish continental shelf but could be found in other areas with similar environmental conditions. The epifauna is less diverse and comprised of Paguridae, Hydrozoa, *Astropecten irregularis*, *Caridea*, and *Pagurus bernhardus*. The burrowing forms are absent owing to the sandier nature of the substratum. The description of this biotope is based on video data so the characterizing fauna include only those species with an epifaunal expression. This epifaunal biotope may be associated with infaunal biotopes described for similar environmental conditions. Due to the mobile nature of the characterizing species, this biotope may not

always be observed at the locations used to define this biotope and can be found in other areas with similar environmental conditions where it hasn't been observed previously. (Information from JNCC, 2022).

### ↓ Depth range

10-20 m, 20-30 m, 50-100 m

### 🏛️ Additional information

Hughes (1998b) noted that *Ophiura* spp. sometimes occur in large numbers on sedimentary habitats but not at the densities typical of brittlestar beds. These aggregations of *Ophiura* spp. have received less attention than other bed-forming species (e.g. *Ophiothrix* and *Ophiocomina*) and less is known about their ecology or population dynamics (Tyler 1976; cited in Hughes, 1998b). This biotope is dominated by *Ophiura ophiura* but few other epifaunal species. The density of *Ophiura ophiura* probably varies between locations and instances of this biotope. For instance, *Ophiura ophiura* was recorded as 'occasional' or 'super-abundant' in this biotope (JNCC, 2022). The equivalent density ranges from 1-9 /1000m<sup>2</sup> to 10-99 /m<sup>2</sup> in large (>15 cm) individuals or from 1-9/ 100m<sup>2</sup> to 100-999 /m<sup>2</sup> for small (3-15 cm) individuals. Therefore, the sensitivity review is based on the biology and sensitivity of *Ophiura ophiura*, with additional inferences from other *Ophiura* species (especially *Ophiura albida* and *Ophiura sarsi*). Similarly, its ecology is inferred from dense aggregations of other *Ophiura*, in particular *Ophiura albida* and *Ophiura sarsi*.

### ✓ Listed By

- none -

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## Sensitivity review

### Sensitivity characteristics of the habitat and relevant characteristic species

This biotope (SS.SSa.CMuSa.Ooph) is an epifaunal community dominated by the brittlestar *Ophiura ophiura*. Other mobile epifauna such as starfish, shrimp and hermit crabs are also present in low numbers, together with a few hydroids, presumably attached to pebbles or large hard substrata. *Ophiura ophiura* is a common boreo-lusitanian brittlestar recorded from North Norway and Iceland, south to the Azores, Madeira and into the Mediterranean and the Black Sea, frequent in the North Sea and Scandinavian waters and into the transitional area between the North Sea and the Baltic (Mortensen, 1927; Ursin, 1960; Tyler, 1977a; Feder, 1981; Southward & Campbell, 2006; OBIS, 2022). It is a large *Ophiura* growing up to 3.5 cm across the disc with arms up to 12 cm in length. It is omnivorous, an active predator capable of capturing and/or engulfing prey, but also a scavenger and detritivore (Feder, 1981; Feder & Pearson, 1988; Boos *et al.*, 2010). Its diet depends on the species available but it will prey on polychaetes (even *Philine aperta*), crustaceans (inc. isopods, amphipods), small bivalves (e.g. *Spisula*, *Mytrea*), other ophiuroids (e.g. the arms of *Ophiura albida*), larvae, nematodes, meiofauna, fish fragments and diatoms. In Loch Linnhe, Feder & Pearson (1998) noted that also fed on fibres (probably from pulp mill effluent) and plant debris typical of the Loch bed. Feder (1981) concluded that *Ophiura ophiura* influences the infaunal community wherever it is common.

In this biotope, *Ophiura ophiura* was recorded as 'occasional' or 'super-abundant' on the SACFOR scale (JNCC, 2022). The equivalent density ranges from 1-9 /1000m<sup>2</sup> to 10-99 /m<sup>2</sup> in large (>15 cm) individuals or from 1-9/ 100m<sup>2</sup> to 100-999 /m<sup>2</sup> for small (3-15 cm) individuals. Its population density varies from low to high depending on location but the dominant populations characteristic of this biotope are not well documented in the literature. Caspers (1980) reported a monoculture on *Ophiura ophiura* (as *texturata*) in parts of a sewage dumping site in the southern North Sea, composed of adults and juveniles with a density of up to 140 per 0.1 m<sup>2</sup> (1,400 /m<sup>2</sup>) where it fed on the rich organic nutrients present. However, high densities of bivalves (*Abra alba*) or polychaetes in other parts of the dump site excluded *Ophiura ophiura*, probably due to space limitations (Caspers, 1980). Ursin (1960) noted that *Ophiura ophiura* reached high densities in the Limfjord where it did not grow very large feeding on detritus, but that it grew larger, in low densities, in the Kattogat where it was carnivorous. Hence growth rate and density were probably related to the food source (Ursin, 1960). Ellis *et al.* (2013) described an inshore community in the Bristol Channel and the western English Channel, at 30-130 m dominated by *Ophiura ophiura*, *Crangon* and *Liocarcinus*, where the average abundance of *Ophiura ophiura* was reported to be 2.13 per tow. Other species of *Ophiura* are reported to form dense beds. A bed of *Ophiura albida* with *Ophiura ophiura* was reported in the Wash with densities of *Ophiura albida* as high as 700/m<sup>2</sup> or 1,500 /m<sup>2</sup> (Dipper *et al.*, 1989; Hughes, 1998b). In the densest beds, the *Ophiura albida* were spread over the seabed with their arms just overlapping (Dipper *et al.*, 1989). Off the Pacific coast of Japan, Fujita & Ohta (1989) examined a dense bed of *Ophiura sarsi* at 280 m that comprised 99% of the epifauna, reached a density of 373 /m<sup>2</sup> (124 g/m<sup>2</sup>) and covered 96% of the seabed over an area of 3 km<sup>2</sup>. Most were 1 cm disc diameter and sat with their disc and distal part of the arms raised above the sediment. They were evenly spaced but avoid physical contact with each other. They also formed 'halos' (clear areas) around sea anemones (potential predators) but not around sea cucumbers or sponges. Dense aggregations of overlapping individuals occurred occasionally, probably around carrion. Fujita & Ohta (1990) reported that the *Ophiura sarsi* beds varied in density from 30 to several hundred per sq. metre, from 200-600 m in depth and reached their maximum density (ca 1000 /m<sup>2</sup>) at ca 350 m but were sparse above 200 m. Fujita & Ohta (1990) suggested that the 200 m cut-off was probably due to food availability, hydrography or temperature but noted that no evidence was available. The beds were composed of a range of size classes dominated by large individuals, and that size increased with depth. Recruitment was good in the shallow areas (200-300 m) but poor at depth (>400 m) possibly due to predation by other ophiuroids. Fujita & Ohta (1990) noted that size was smallest in the high-density sites with good recruitment but that size increased with depth and lower density, although biomass remained the same. The spatial structure of high densities of *Ophiura* spp. may exhibit a similar pattern.

Overall, *Ophiura ophiura* is the dominant species in this biotope, an omnivore that itself influences the composition of the infauna of the underlying sediment and is capable of feeding on detritus from a variety of

sources. *Ophiura ophiura* is a mobile species that spends the majority of its time at the surface of the sediment (Mortensen, 1927; Feder, 1981; Skold, 1998; Boos *et al.*, 2010). However, the reasons that it occurs in high densities or dominates particular areas are unclear. It is probably attracted to areas by food availability and, together with good recruitment, comes to dominate the area, especially if local conditions reduce or exclude predators. Alternatively, good recruitment into areas of high food availability may result in self-sustaining aggregations. Ophiuroid recruitment is affected by hydrography (Tyler, 1977b) so aggregations may also depend on local hydrography. Therefore, the sensitivity assessment is based on the sensitivity of *Ophiura ophiura* together with information on the structure of aggregations in other *Ophiura* species, where relevant. The other species described in the biotope are mobile scavengers that are probably ubiquitous in the surrounding area and do not influence the overall sensitivity of the biotope.

## Resilience and recovery rates of habitat

*Ophiura* spp. are opportunistic species with short generation times, rapid reproduction, and high dispersal potential. Mortensen (1927) suggested that the brittlestar reached sexual maturity in its third year at ca 7-11 mm disc diameter and suggested that large specimens of ca 3 cm disc diameter were 5-6 years of age. Boolootian (1966) reported that *Ophiura ophiura* bred in August and September on the Baltic coast of Sweden. Tyler (1977a) found that *Ophiura ophiura* had a protracted breeding season, and adult size classes were less distinct (Tyler, 1977a). *Ophiura ophiura* is reproductively dormant during summer, with oocytes carried over winter (Tyler, 1977a). Ophiopluteus larvae occur between March and October but year-round spawning is unlikely and, like other brittlestar species, oocytes are probably laid down at the end of the spawning period, lay dormant over winter and develop in the following year (Wood *et al.*, 2010). Temperature is a common spawning trigger in Ophiuroids but while *Ophiura ophiura* spawned at 12.5°C in 1974 but in 1973 larvae were found at 7.25°C in the coldest month of the year, so Tyler (1977a) suggested another environmental factor was involved. The ophiopluteus larvae are planktotrophic and the larvae of *Ophiura ophiura* are described by Webb & Tyler (1985) and Stöhr (2005).

Gage (1990) suggested a lifespan of 5 -6 years for *Ophiura ophiura* from the west of Scotland, which agreed with Mortensen's (1927) estimate for the British Isles. However, analysis of growth rings in specimens from the German Bight suggested a maximum age of 9 yr at a disk diameter of 15.2 mm (Dahm, 1993). Dahm (1993) noted that growth rates and lifespan may vary regionally but that prior studies probably underestimated age and overestimated growth rate. Similarly, observations by Ursin (1960) and Fujita & Ohta (1990) suggest that growth rates and size may depend on population density, and food source (detritivory vs. carnivory). In addition, Guillou & Robert (1979, cited in Lawrence, 1990) suggested that the lifespan of *Ophiura ophiura* (as *texturata*) in the Mediterranean was lower than in the North sea, possibly due to predation.

Ophiuroids are unknown for their ability to regenerate lost limbs and even damage to their disc (Boolootian, 1966; Emson & Wilkie, 1980; Sköld, 1998). Ophiuroids are known to undergo shed their arms (autotomy) as a potential defence mechanism against predators, and the shed arms are reported to wriggle possibly to distract the predator (Wilkie, 1978; Emson & Wilkie, 1980; Sköld, 1998; Sköld & Rosenberg, 1996). Sköld & Rosenberg (1996) cited Hyman (1955) with an arm regeneration rate of 25 mm/year in *Ophiura ophiura*.

Ophiuroids demonstrate sporadic and unpredictable recruitment (Buchanan 1964) even though they have long-lived pelagic larvae with a high dispersal potential. Tyler & Banner (1977) noted that the density of *Ophiura albida* was greatest in areas of a tidal gyre in deeper water (20 m) in Oxwich Bay, Bristol Channel. They suggested that the accumulation of fine sediment and organic matter was favourable for the settlement and growth of ophiuroid larvae and, hence, that local hydrography influenced recruitment in the ophiuroid and other species. Tyler (1977b) and Tyler & Banner (1977) also noted that this area supported a diverse community of opportunistic species but that recruitment of the other species was probably influenced by the predation by *Ophiura*. Balch *et al.* (1999) reported a pulse of *Ophiura* spp. settlement over a short (9-day) period in St Margaret's Bay, Nova Scotia. The single pulse of settlement represented 63% of that year's (1993) settlement of *Ophiura* spp. and was caused by an unpredictable, mass-water intrusion into the bay. Olivier & Retiere (1998) also noted that *Ophiura ophiura* was transported (drifted) during the

tidal cycle in the English Channel.

Boos & Franke (2006) found that *Ophiura* sp. were amongst the six most common species of brittlestar in the German Bight (North Sea) and were part of a stable community of brittlestars present for ca 130 years. Gilkinson *et al.* (2005) reported that *Ophiura sarsi* increased in abundance directly after dredging with the largest increases seen two years later. They noted that the increase in abundance was due to the migration of adults into the affected area rather than recruitment. *Ophiura ophiura* and *Ophiura albida* were recorded regularly in baited traps, sometimes in relatively high numbers, indicating that these species are mobile and exhibit scavenging behaviour (Groenewold & Fonds 2000). *Ophiura ophiura* has been observed scavenging in trawl tracks after the passage of a scallop dredge although divers noted that many were damaged (Ramsay *et al.*, 1998). Sköld (1998) demonstrated that *Ophiura ophiura* was a fast-moving species that responded rapidly to an attack and would rear up before moving away from the threat across the substratum. Feder (1981) reported that *Ophiura ophiura* could actively hunt prey, coil its arms around them or 'jump' on them, clearing the substratum in the process.

Constantino *et al.* (2009) examined the effect of clam dredging on the sediment community at different depths. At 18 m that noted that *Ophiura ophiura* was removed from dredge tracks directly after trawling but had returned within 1 day and were present at least 96 days after trawling. However, as scavengers *Ophiura ophiura* may be expected to be attracted to discards and injured organisms in the path of fishing gear. However, Bergmann & Moore (2001b) reported 100% mortality in *Ophiura ophiura* after trawling and aerial exposure and high mortality in specimens returned immediately after trawling. The effect of trawling varies between studies depending on the gear used and the duration of aerial exposure. In their summary, Bergmann & Moore (2001b) noted that while some studies concluded that *Ophiura ophiura* was resilient to fishing gear due to their high capacity for regeneration and some studies had found a significant increase in *Ophiura ophiura* densities after experimental trawling, other studies had shown a significant reduction in ophiuroid densities due to fishing disturbance. They concluded that the species continued abundance in the Clyde Sea suggested that populations exposed to trawling could be restocked from adjacent populations and that brittlestar mortality from trawling could be outweighed by the species' reproductive resilience and the possible reduction in the density of its predators or competitors by fishing activities (Bergmann & Moore, 2001b).

**Resilience assessment.** *Ophiura* spp. are opportunistic species with short generation times, rapid reproduction, and high dispersal potential. *Ophiura ophiura* reproduces annually, although larval recruitment is probably controlled by local hydrography and food availability, and may be prevented by a high density of competitors (e.g. bivalves and polychetes) (Caspers, 1980). Adults can probably recruit to areas due to their high mobility, although they may also be transported by bedload transport. Overall, recruitment by adults or larvae is probably good and has been suggested to offset considerable potential mortality due to fishing (Bergmann & Moore, 2001b). The factors that control the development of the densities or dominance of *Ophiura ophiura* typical of this biotope are unclear, but likely to be food supply, favourable hydrography for larval recruitment and the density of competitors or predators. Nevertheless, the species demonstrates good recruitment, the ability to regenerate damage, adult mobility and resilience in the face of significant physical disturbance and bycatch from fishing activities. Therefore, resilience is probably 'High' (< 2 years) when resistance is 'Medium' or 'Low' with Medium confidence. Resilience is also probably 'High' when resistance is 'None' but the time taken for dense populations to develop or for the population to dominate the community is unknown. Therefore, a more precautionary assessment of 'Medium' (2- 10 years) is suggested, albeit with 'Low' confidence.

## Hydrological Pressures

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

*Ophiura ophiura* is a common boreo-lusitanian brittlestar recorded from North Norway and Iceland, south to

the Azores, Madeira and into the Mediterranean and the Black Sea, frequent in the North Sea and Scandanavian waters and into the transitional area between the North Sea and the Baltic (Mortensen, 1927; Ursin, 1960; Tyler, 1977a; Feder, 1981; Southward & Campbell, 2006; OBIS, 2022). Therefore, the species is likely to experience a wide range of temperature regimes. OBIS (2022) lists records of *Ophiura ophiura* from sea surface temperatures of 5 to 25°C although the majority of records were from 10-15°C.

Temperature is a common spawning trigger in Ophiuroids but while *Ophiura ophiura* spawned at 12.5°C in 1974 but in 1973 larvae were found at 7.25°C in the coldest month of the year, so Tyler (1977a) suggested another environmental factor was involved. Wood *et al.* (2010) exposed *Ophiura ophiura* to 10.5°C and 15°C in the laboratory; temperatures that they suggested were normal for spring and summer in the waters of Plymouth, UK. They reported a seven-fold increase in metabolic rate (measured as oxygen uptake) between 10.5°C and 15°C (an increase of 4.5°C), together with an increase in speed of movement, but no mortality in the 40-day experiment. However, Wood *et al.* (2010) suggested that the increase in metabolic rate could result in a reduction in arm regeneration and growth, and impact the survivorship of individuals in the long term.

**Sensitivity assessment.** The distribution of *Ophiura ophiura* suggests that it is probably resistant to a 2°C change in temperature for a year. Exposure to a short-term acute increase of 5°C may have an effect on the metabolism of *Ophiura ophiura* but there is no evidence to suggest that mortality would result. Therefore, a resistance of '**High**' is suggested but with Low confidence. Therefore, resilience is '**High**', so the biotope is probably '**Not sensitive**' at the benchmark level.

#### Temperature decrease (local)

**None**

Q: High A: Medium C: Medium

**Medium**

Q: Low A: NR C: NR

**Medium**

Q: Low A: Low C: Low

*Ophiura ophiura* is a common boreo-lusitanian brittlestar recorded from North Norway and Iceland, south to the Azores, Madeira and into the Mediterranean and the Black Sea, frequent in the North Sea and Scandanavian waters and into the transitional area between the North Sea and the Baltic (Mortensen, 1927; Ursin, 1960; Tyler, 1977a; Feder, 1981; Southward & Campbell, 2006; OBIS, 2022). Therefore, the species is likely to experience a wide range of temperature regimes. OBIS (2022) lists records of *Ophiura ophiura* from sea surface temperatures of 5 to 25°C although the majority of records were from 10-15°C.

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**Sensitivity assessment.** The distribution of *Ophiura ophiura* suggests that it is probably resistant to a 2°C change in temperature for a year. Exposure to a short-term acute increase of 5°C may result in mass mortality of *Ophiura ophiura* in the affected area. However, the biotope is probably protected by its depth and only the most shallow example may be vulnerable. Therefore, resistance is assessed as '**None**', resilience as '**Medium**', and sensitivity assessed as '**Medium**' at the benchmark level.

#### Salinity increase (local)

**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

Echinoderms are osmoconformers and generally stenohaline due to their lack of an excretory organ, and their poor ability to osmoregulate (Binyon, 1966; Stickle & Diehl, 1987). Information on the effects of hypersaline effluents (>40) is limited (Roberts *et al.*, 2010b). Fernandez-Torquemada *et al.* (2008) reported that echinoderms (unspecified) were lost from *Posidonia* beds exposed to hypersaline effluents. Sanchez-Lizaso *et al.* (2008) reported increased mortality of *Paracentrotus lividus* at 40.5 to 41 psu in experimental aquaria. Chesher (1971, 1975) also reported significant mortality of echinoderms in *Posidonia* beds due to



brine effluent but the mortality was attributed to copper contamination in the effluent. Roberts *et al.* (2010b) noted that, in most cases, the effects of brine effluents were limited to within 10s of metres of the outfalls.

**Sensitivity assessment.** This biotope is unlikely to be exposed to hypersaline (brine) effluents unless the outfalls are placed at depth (although hypersaline effluents will sink) and it is a mobile species, likely to move away from the vicinity of the outfall. However, there is no evidence of the effect of hypersaline conditions on *Ophiura ophiura* or its aggregations on which to base an assessment.

### Salinity decrease (local)

**Medium**

Q: Low A: NR C: NR

**High**

Q: High A: Medium C: Medium

**Low**

Q: Low A: Low C: Low

Echinoderms are osmoconformers and generally stenohaline due to their lack of an excretory organ, and their poor ability to osmoregulate (Binyon, 1966; Stickle & Diehl, 1987). However, several species are recorded from extreme salinities (Stickle & Diehl, 1987; Russell, 2013). *Ophiura ophiura* (as *texturata*) was recorded from 18 ppt in the Black Sea, from an average of 20 ppt in the transitional area between the North Sea and the Baltic Sea, from 21 to 31 ppt in the German Waddensea, and from 27 ppt from the delta region of the Netherlands (Ursin, 1960; Stickle & Diehl, 1987; Russell, 2013). Ursin (1960) cites records from the estuaries of the rivers Crouch and Roach on the south English coast. Mortensen (1927) notes that it may be found in the lower intertidal, where it buries itself in the sand as the tide recedes. OBIS (2022) lists records of *Ophiura ophiura* at sea surface salinities between 5 and 35 psu although the majority are from 30-35 psu. However, Ursin (1960) commented it was uncertain if it could reproduce at low salinities (ca 20 ppt) because Thorson (1946) did not find any larvae in the Øresund.

**Sensitivity assessment.** *Ophiura ophiura* can probably survive a change in salinity from full (30-35) to reduced (18-30) for a year, perhaps more. However, it is unclear what density of individuals or populations occurred at the low salinities recorded above. This biotope is only recorded from full salinity (30-35) conditions. If, (as Ursin, 1960 suggests) low salinities impair recruitment, where good recruitment is required to maintain the dense aggregation of this species a change to reduced salinity conditions may result in a reduction in the population density in the short-term due to loss of recruitment or the species moving to more suitable conditions. Therefore, resistance is assessed as '**Medium**' but with '**Low**' confidence. Hence, resilience is '**High**' and sensitivity is assessed as '**Low**'.

### Water flow (tidal current) changes (local)

**High**

Q: Low A: NR C: NR

**High**

Q: High A: High C: High

**Not sensitive**

Q: Low A: Low C: Low

No information on tidal streams in this biotope (SS.SSa.CMuSa.Ooph) was available (JNCC, 2022). However, *Ophiura ophiura* was recorded in biotopes from very weak to moderately strong (negligible to 1.5 m/s) tidal streams (Connor *et al.*, 2004; Tillin & Tyler-Walters, 2014b). In addition, *Ophiura ophiura* is a sediment generalist recorded from silty mud, fine to very fine muddy sand, sandy mud and clean fine sands (Connor *et al.*, 2004; Tillin & Tyler-Walters, 2014b). Local hydrography is important for recruitment in ophiuroids (Tyler, 1977b; Tyler & Banner, 1977; Balch *et al.*, 1999). Olivier & Retiere (1998) noted that *Ophiura ophiura* was transported (drifted) during the tidal cycle in the English Channel. Extreme increases in water flow, that could remove the sediment, would adversely affect the biotope and cause the characteristic brittlestar population to relocate. However, a change in the water flow of 0.1 to 0.2 m/s may reduce fines and favour more sandy sediments but *Ophiura ophiura* is recorded from muddy sands and sands. Therefore, resistance is assessed as '**High**' based on expert judgement. Hence, resilience is assessed as '**High**' and sensitivity as '**Not sensitive**' at the benchmark level.

### Emergence regime 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

This biotope (SS.SSa.CMuSa.Ooph) is recorded from 10-100 m in depth. Hence, emergence is '**Not relevant**'.

#### 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**

This biotope (SS.SSa.CMuSa.Ooph) is recorded from very exposed to moderately exposed wave conditions (JNCC, 2022), where depth probably attenuates wave-mediated water movement to allow the muddy muddy sands that characterize the biotope to persist. Local hydrography is important for recruitment in ophiuroids (Tyler, 1977b; Tyler & Banner, 1977; Balch *et al.*, 1999). Olivier & Retiere (1998) noted that *Ophiura ophiura* was transported (drifted) during the tidal cycle in the English Channel. Extreme wave action from seasonal storms may be detrimental. For example, Rees *et al.* (1977) examined shallow benthic communities after major storms in the winter of 1975-1976 in North Wales. In Red Wharf Bay, Anglesey *Ophiura ophiura* (as *texturata*) was one of the most numerous species washed ashore. In Colwyn Bay, the muddy sands were scored away to the underlying gravel and *Ophiura albida* was removed in the process (0% survival). The sediments in Red Wharf Bay and Beaumaris Bay were modified but remained muddy (Rees *et al.*, 1977). Therefore, seasonal storms have the potential to move and/or resuspend sediment and move and/or strand dense populations of brittlestars and result in loss of the biotope, depending on their depth and the severity of the storm. However, a 3-5% change in significant wave height (the benchmark) is unlikely to have a significant on the biotope, especially in the deeper examples. Therefore, resistance is assessed as '**High**', resilience as '**High**' and sensitivity as '**Not sensitive**'.

#### Chemical Pressures

**Resistance**

**No evidence (NEv)**

Q: **NR** A: **NR** C: **NR**

**Resilience**

**Not relevant (NR)**

Q: **NR** A: **NR** C: **NR**

**Sensitivity**

**No evidence (NEv)**

Q: **NR** A: **NR** C: **NR**

#### Transition elements & organo-metal contamination

Adult echinoderms such as *Ophiothrix fragilis* are known to be efficient concentrators of heavy metals including those that are biologically active and toxic (Ag, Zn, Cd and Co) (Hutchins *et al.*, 1996). There was no information on the effect of this bioaccumulation. Gounin *et al.* (1995) studied the transfer of heavy metals (Fe, Mn, Pb, Cu and Cd) through *Ophiothrix* beds. They concluded that heavy metals ingested or absorbed by the animals transited rapidly through the body and were expelled in the faeces and did not appear to accumulate in their tissues. Studies by Deheyn & Latz (2006) at the Bay of San Diego found that heavy metal accumulation in brittlestars occurs both through dissolved metals as well as through diet, to the arms and disc, respectively. Similarly, Sbaihat *et al.* (2013) measured concentrations of heavy metals (Cu, Ni, Cd, Co, Cr and Pb) in the body of *Ophiocoma scolopendrina* collected from the Gulf of Aqaba, and found that most concentration was found in the central disc rather than arms and no simple correlations could be found between contaminant and body length. It is logical to suppose that brittlestar beds would be adversely affected by major pollution incidents such as oil spills, or by continuous exposure to toxic metals, pesticides, or the antiparasite chemicals used in cage aquaculture. However, there are no field observations of epifaunal brittlestar beds being damaged by any of these forms of pollution, and no evidence of the toxicity effects of heavy metal accumulation on brittlestars was found.

#### Hydrocarbon & PAH contamination

**No evidence (NEv)**

Q: **NR** A: **NR** C: **NR**

**Not relevant (NR)**

Q: **NR** A: **NR** C: **NR**

**No evidence (NEv)**

Q: **NR** A: **NR** C: **NR**

Echinoderms tend to be very sensitive to various types of marine pollution (Suchanek, 1993; Newton & McKenzie, 1995). Adult *Ophiothrix fragilis* have been documented to be intolerant to hydrocarbons (Newton & McKenzie, 1995). The sub-cuticular bacteria that are symbiotic with *Ophiothrix fragilis* are reduced in number following exposure to hydrocarbons. Exposure to ca 30,000 ppm oil reduces the bacterial load by

50% and brittlestars begin to die. All the *Ophiothrix* were dead after 6 days at ca 30,000 ppm but showed some recovery at ca 300 ppm. (Newton & McKenzie, 1995). Specimens of *Amphiura filiformis*, *Ophiofrix fragilis* and *Ophiura ophiura* collected from the North Sea in June 1993 after the Braer oil spill were found to have a reduced number of sub-cuticular bacteria as the oil contamination in the sediment increased, although sample size meant that the results were only significant for *Amphiura* (Newton & McKenzie, 1995). The water-accumulated fraction of diesel oil was acutely toxic to *Ophiothrix fragilis* and *Ophiocomina nigra*, although no field observations of beds being damaged by hydrocarbon pollution have been found (Hughes, 1998b). The majority of specimens of *Ophiocomina nigra* were killed by experimental exposure to 5 ppm of the dispersant BP1005 (Smith, 1968). However, no direct evidence of resultant mortality in *Ophiura* spp. was found.

#### Synthetic compound contamination

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

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

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

Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995) but there was no more detailed information than this broad statement. Brittlestar beds may be damaged by chemical pollutants such as pesticides or anti-parasite chemicals used in aquaculture, but no direct evidence was found.

#### Radionuclide contamination

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

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

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

Adult echinoderms such as *Ophiothrix fragilis* were reported to be efficient concentrators of radionuclides (Hutchins *et al.*, 1996). However, there was no information available about the effect of this bioaccumulation.

#### Introduction of other substances

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

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

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

No evidence was found

#### De-oxygenation

Low  
Q: High A: High C: Medium

High  
Q: Medium A: Medium C: Medium

Low  
Q: Medium A: Medium C: Medium

In their review of hypoxia, Vaquer-Sunyer & Duarte (2008) noted that echinoderms were amongst the most resistant to hypoxia after molluscs, and cited a sublethal threshold for *Ophiura albida* of 0.79 mg/l O<sub>2</sub> or 2.0 mg/l O<sub>2</sub> depending on the source. Diaz & Rosenberg (1995) listed *Ophiura albida* among species resistant to severe hypoxia. Riedel *et al.* (2012) used in situ chambers to manipulate oxygen concentrations at the sediment surface. They reported that mortality of *Ophiura quinque maculata* occurred at the transition between hypoxia (median of 0.03 ml/l) and anoxia (median duration 6.1 hours). However, 13 species, including *Ophiura* spp. only died after 8.2 to 19.1 hours of anoxia.

Theede *et al.* (1969) reported an LD50 of 32 hours when *Ophiura albida* was exposed to 0.15 ml O<sub>2</sub>/l (ca 0.21 mg/l O<sub>2</sub>) which decreased to 30 hours with the addition of 50 mg/l of sodium sulphide. Theede *et al.* (1969) suggested that *Ophiura albida* was one of the three most resistant species they tested. However, Vistisen & Vismann (1997) suggested that Theede *et al.* underestimated mortality rates due to methodological problems. Vistisen & Vismann (1997; cited in Gray *et al.*, 2002) reported LT<sub>50</sub>s of <0.1 mg/l O<sub>2</sub> (60 hours), 0.3 mg/l O<sub>2</sub> (144 hours), 0.5 mg/l O<sub>2</sub> (336 hours) in *Ophiura albida*, which also exhibited an initial escape response and lifted their disc's into the water column at 0.1 to 1.1 mg/l O<sub>2</sub>. The presence of hydrogen sulphide decreased the lethal time. At <0.1 mg/l O<sub>2</sub> and 2 µM H<sub>2</sub>S, the LT<sub>50</sub> was 43.2 hours and decreased to 8 hours at 0.1 mg/l O<sub>2</sub> and 200 µM H<sub>2</sub>S (Vistisen & Vismann, 1997; cited in Gray *et al.*,

2002). Vistisen & Vismann (1997) noted that even very small increases in H<sub>2</sub>S decreased survivability significantly.

Belley *et al.* (2010) reported a high abundance of surface-feeding *Ophiura* spp. in the persistently hypoxic waters of the lower St Lawrence estuary. *Ophiura* spp. dominated (61.32 individuals/m<sup>2</sup>) in the hypoxic waters (<20% O<sub>2</sub>, ca <6.5 mg/l) but was less abundant in normoxic waters.

Stachowitsch (1984) observed the mass mortality of benthic organisms in the Gulf of Trieste, northern Adriatic Sea, caused by the onset of severe hypoxia (oxygen depletion) in the near-bottom water. A wide variety of organisms was affected, including burrowing invertebrates, sponges, and the brittlestar *Ophiothrix quinquemaculata*, a dominant component of the local epifaunal community. All of the brittlestar *Ophiothrix quinquemaculata* were dead within 2-3 days, whereas *Ophiura ophiura* (as *texturata*) survived until day 3 at some stations. This event was likely caused by a combination of unfavourable weather and tidal conditions, at the same time as a period of maximal organic input from coastal pollution and dying phytoplankton. Water exchange in the Gulf was poor, and the area tended to accumulate sediment and suspended organic material, however, no estimate of oxygen concentrations was given (Stachowitsch, 1984). Mass mortality of *Ophiura albida* was also reported after eutrophication and a thermocline in the eastern German Bight in 1982 (Lawrence, 1996). Summer mass mortalities in the 1980s due to hypoxia caused by eutrophication and stratification were reported in the fjords of western Sweden in which *Ophiura* spp. were killed. *Ophiura albida* was the only echinoderm to recover after 1988 (Lawrence, 1996).

**Sensitivity assessment.** The above evidence suggests that *Ophiura* spp. are resistant to severe hypoxia and only die once conditions become anoxic, under controlled conditions. However, *Ophiura ophiura* was reported to have died after three days during the severe hypoxia in the Gulf of Trieste, although the level of hypoxia was not quantified. *Ophiura ophiura* would probably survive at 2 mg/l O<sub>2</sub> for a week (see benchmark) but survival would decrease as the oxygen concentration decreased, the duration of the event increased and hydrogen sulphide increased in concentration. However, *Ophiura ophiura* is a mobile species capable of moving away from unsuitable local conditions. Therefore, resistance is assessed as 'Low' to represent the potential for significant mortality of *Ophiura ophiura* within the biotope after prolonged exposure (several days) to oxygen concentrations below 2 mg/l. Resilience is probably 'High' so sensitivity is assessed as 'Low'.

Nutrient enrichment	<b>Medium</b>	<b>High</b>	<b>Low</b>
	Q: Low A: NR C: NR	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

Mass mortalities of brittlestars, including *Ophiura* spp. have been attributed to eutrophication, in combination with stratification and resultant hypoxia (see Lawrence, 1996 above). Caspers (1980) reported a monoculture on *Ophiura ophiura* (as *texturata*) in parts of a sewage dumping site in the southern North Sea, composed of adults and juveniles with a density of up to 140 per 0.1 m<sup>2</sup> (1,400 /m<sup>2</sup>) where it fed on the rich organic nutrients present. However, high densities of bivalves (*Abra alba*) or polychaetes in other parts of the dump site excluded *Ophiura ophiura*, probably due to space limitations (Caspers, 1980). Ursin (1960) noted that *Ophiura ophiura* reached high densities in the Limfjord where it did not grow very large feeding on detritus, but that it grew larger, in low densities, in the Kattegat where it was carnivorous. Hence growth rate and density were probably related to the food source (Ursin, 1960).

Feder & Pearson (1988) examined the benthic epifauna of Loch Eil and Loch Linnhe, 16-18 years after pulp mill effluent was discharged into the Lochs. *Ophiura ophiura* was found to feed on detritus, plant material and pulp fibres in the Loch Linnhe, in addition to its usual prey items. However, *Ophiura ophiura* was common in Loch Linnhe and rare in Loch Eil. Feder & Pearson (1988) concluded that the absence of *Ophiura* and other species from Loch Eil was due to the change in sedimentary conditions from the pre-pollution (1963) to intermittently deoxygenated surface sediments by 1980. Pulp mill effluent ceased in 1980, and several species returned by 1982 but not *Ophiura*.

**Sensitivity assessment.** The evidence suggests that eutrophication, organic enrichment and resultant hypoxia have resulted in mass mortalities of ophiuroids, including *Ophiura ophiura* (see 'deoxygenation' above). No evidence of the effect of nutrient enrichment (nitrogen and phosphorus) on the biotope was found. However, the mass mortalities reported in the past suggest that eutrophication (e.g. a change from 'good' to 'moderate' water quality, see benchmark) could result in mortality if local conditions allowed for hypoxia to occur. Therefore, resistance is assessed as '**Medium**', as a precaution, albeit with 'Low' confidence since the level of enrichment is not quantified in the evidence. Hence, resilience is '**High**' and sensitivity is assessed as '**Low**'.

### Organic enrichment

**High**

Q: Low A: NR C: NR

**High**

Q: High A: High C: High

**Not sensitive**

Q: Low A: Low C: Low

Mass mortalities of brittlestars, including *Ophiura* spp. have been attributed to eutrophication, in combination with stratification and resultant hypoxia (see Lawrence, 1996 above). Caspers (1980) reported a monoculture on *Ophiura ophiura* (as *texturata*) in parts of a sewage dumping site in the southern North Sea, composed of adults and juveniles with a density of up to 140 per 0.1 m<sup>2</sup> (1,400 /m<sup>2</sup>) where it fed on the rich organic nutrients present. However, high densities of bivalves (*Abra alba*) or polychaetes in other parts of the dump site excluded *Ophiura ophiura*, probably due to space limitations (Caspers, 1980). Ursin (1960) noted that *Ophiura ophiura* reached high densities in the Limfjord where it did not grow very large feeding on detritus, but that it grew larger, in low densities, in the Kattegat where it was carnivorous. Hence growth rate and density were probably related to the food source (Ursin, 1960).

Feder & Pearson (1988) examined the benthic epifauna of Loch Eil and Loch Linnhe, 16-18 years after pulp mill effluent was discharged into the Lochs. *Ophiura ophiura* was found to feed on detritus, plant material and pulp fibres in the Loch Linnhe, in addition to its usual prey items. However, *Ophiura ophiura* was common in Loch Linnhe and rare in Loch Eil. Feder & Pearson (1988) concluded that the absence of *Ophiura* and other species from Loch Eil was due to the change in sedimentary conditions from the pre-pollution (1963) to intermittently deoxygenated surface sediments by 1980. Pulp mill effluent ceased in 1980, and several species returned by 1982 but not *Ophiura*.

**Sensitivity assessment.** The evidence suggests that eutrophication, organic enrichment and resultant hypoxia have resulted in mass mortalities of ophiuroids, including *Ophiura ophiura* (see 'deoxygenation' above). However, the observation of high densities of *Ophiura ophiura* in a sewage sludge dumping ground, on organically enriched sediment (Caspers, 1980) suggests that *Ophiura ophiura* and, hence, this biotope may be resistant to and even benefit from areas of organic enrichment (Ursin, 1960; Caspers, 1980; Feder & Pearson, 1988) in the absence of hypoxia. Therefore, resistance is assessed as '**High**', albeit with 'Low' confidence since the level of enrichment is not quantified in the evidence. Hence, resilience is '**High**' and sensitivity is assessed as '**Not sensitive**'.

## A Physical Pressures

### Physical loss (to land or freshwater habitat)

**Resistance**

**None**

Q: High A: High C: High

**Resilience**

**Very Low**

Q: High A: High C: High

**Sensitivity**

**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

f the sediment that characterizes the biotopes was replaced with rock substrata, this would represent a fundamental change to the physical character of the biotope. The characterizing species would no longer be supported and the biotopes would be lost and/or reclassified. Therefore, resistance to the pressure is considered '**None**', and resilience '**Very low**', given the permanent nature of this pressure. Sensitivity has been assessed as '**High**'. Although no specific evidence is described, confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

#### Physical change (to another sediment type)

**High**

Q: Low A: NR C: NR

**High**

Q: High A: High C: High

**Not sensitive**

Q: Low A: Low C: Low

*Ophiura ophiura* is a sediment generalist recorded from silty mud, fine to very fine muddy sand, sandy mud, clean fine sands, gravels and broken shells (Connor *et al.*, 2004; Boos & Franke, 2006; Boos *et al.*, 2010 Tillin & Tyler-Walters, 2014b), while this biotope (SS.SSa.CMuSa.Ooph) is recorded from muddy sands (JNCC, 2022). Caspers (1980) reported a dense population of *Ophiura ophiura* (as *texturata*) on fine, organically-rich, mud at a sewage sludge dumpsite. Boos *et al.* (2010) concluded that *Ophiura ophiura* was relatively unselective of sediment type, as it did not rely on burrowing to escape predators and escaped by quickly moving across the substratum. Hence, a change in sediment type from muddy sands to mud or coarse sediment is unlikely to affect *Ophiura ophiura*. It is unclear if muddy sands are a prerequisite for the development of the dense aggregations of *Ophiura ophiura* that characterize this biotope. As this species is a widespread, common, member of the sedimentary epifauna and a sediment generalist it seems unlikely that sediment type is a prerequisite for the development of the biotope. Therefore, resistance is assessed as '**High**' but with 'Low' confidence. Hence, resilience is assessed as '**High**' and sensitivity as '**Not sensitive**'.

#### Habitat structure changes - removal of substratum (extraction)

**None**

Q: High A: High C: High

**Medium**

Q: Low A: NR C: NR

**Medium**

Q: Low A: Low C: Low

*Ophiura ophiura* is epifaunal, living on the sediment surface and occasionally burrowing into the surface layer. Removal of the sediment to a depth of 30 cm (the benchmark) would remove all of the benthos within the affected area, and result in the loss of the biotope. Therefore, resistance is assessed as '**None**', resilience as '**Medium**' (assuming suitable sediment remains) and sensitivity is assessed as '**Medium**'.

#### Abrasion/disturbance of the surface of the substratum or seabed

**Low**

Q: High A: High C: Low

**High**

Q: Medium A: Medium C: Medium

**Low**

Q: Medium A: Medium C: Low

The effect of fishing gear on sedimentary epifauna has been studied by numerous authors in the past few decades. The effect of trawling on *Ophiura* spp. and other epifauna varies between studies depending on the gear used and sediment type and the survival of bycatch on the gear type and duration of aerial exposure.

Bergman & Van Santbrink (2000b) examined the effect of different types of beam trawls and otter trawls in sandy sediments in the Dutch North Sea. They reported that megafauna (>1 cm) experienced annual fishing mortality of 5-35% mainly due to the direct impact of the trawl on the trawl track or indirectly due to disturbance and predation. In particular, *Ophiura ophiura* experienced between 2 and 12% mortality but there were no significant differences between trawl types examined. Bergman & Van Santbrink (2000b) reported that *Ophiura ophiura* experienced a 7% mortality, across all trawl fisheries in 1994 in the Dutch sector of the North Sea. Bradshaw *et al.* (2000) noted that animals with hard tests, e.g. brittlestars such as *Ophiura* spp. were badly damaged by contact with scallop dredges or beam trawls, although they also reported that the abundance of *Ophiura albida* increased in dredge tracks. Bergman & Hup (1992) reported that the number of small *Ophiura* (0.1-0.4 cm) in the surface sediment did not change after three-fold experimental trawling, probably because they escaped undamaged through meshes. Hinz *et al.* (2012) also reported significant negative effects of queen dredges (for scallops) on *Ophiura ophiura* in the dredge

tracks. The significant differences between the two types of queen dredge were not seen in bycatch but in the tracks, which suggested the effect was due to the direct impact of the dredges used. Smith *et al.* (2000) noted that epifaunal abundance was reduced in otter-trawl tracks during the trawling season (October-March) in the Mediterranean but increased again after the trawling season.

Constantino *et al.* (2009) examined the effect of clam dredging on the sediment community at different depths. At 18 m that noted that *Ophiura ophiura* was removed from dredge tracks directly after trawling but had returned within 1 day and were present at least 96 days after trawling. However, as scavengers *Ophiura ophiura* may be expected to be attracted to discards and injured organisms in the path of fishing gear. Kaiser & Spencer (1995) reported that 96% of *Ophiura ophiura* bycatch were alive after experimental trawling with a 4 m beam trawl but that mortality increased to 19% after 120 hours. Mortality was due to >50% damage to the disc (Kaiser & Spencer, 1995). Bergmann & Moore (2001b) reported 100% mortality in the *Ophiura ophiura* brought onboard as bycatch 14 days after trawling and aerial exposure and high mortality (91%) in specimens returned to the water immediately after trawling. They concluded that earlier studies underestimated mortality because they only monitored mortality for up to five days.

Rumohr & Kujawski (2000) compared historical data on epifauna in the southern North Sea from 1900-1912 with data from 1986. They noted that bivalve populations had declined while scavengers and predators (sea stars, crustaceans and gastropods) have increased in frequency due to the effects of fishing activities. However, they reported that *Ophiura ophiura* was absent from their stations in 1986 but had occurred in 55% of stations in 1900-1912, while other *Ophiura* spp. had increased in frequency. Bradshaw *et al.* (2002) reported that *Ophiura albida* was one of a number of species that increased in abundance over a 60-year period from ca 1939 and 1950 to 1994 in areas of the Irish Sea subject to scallop dredging. They suggested that the life-history characteristics of *Ophiura* spp. (mobility and good regeneration from non-fatal injuries) provided resilience against the long-term impacts of trawling. Callaway *et al.* (2007) reported that *Ophiura ophiura* was one of 12 species to double their spatial presence (distribution) in the North Sea from 1902 to 2000, in spite of fishing activity.

**Sensitivity assessment.** In their summary, Bergmann & Moore (2001b) noted that while some studies concluded that *Ophiura ophiura* was resilient to fishing gear due to their high capacity for regeneration and some studies had found a significant increase in *Ophiura ophiura* densities after experimental trawling, other studies had shown a significant reduction in ophiuroid densities due to fishing disturbance. They concluded that the species continued abundance in the Clyde Sea suggested that populations exposed to trawling could be restocked from adjacent populations and that brittlestar mortality from trawling could be outweighed by the species' reproductive resilience and the possible reduction in the density of its predators or competitors by fishing activities (Bergmann & Moore, 2001b). Therefore, resistance is assessed as '**Low**' based on the potential mortality from direct contact with fishing gear or as bycatch. However, resilience is probably '**High**' so sensitivity is assessed as '**Low**'.

#### Penetration or disturbance of the substratum subsurface

**Low**

Q: High A: High C: Low

**High**

Q: Medium A: Medium C: Medium

**Low**

Q: Medium A: Medium C: Low

*Ophiura ophiura* is epifaunal but can burrow into the surface of the sediment. The effects of penetrative gear are likely to be very similar to the effects of fishing gear that only disturbs the surface of the sediment (see 'abrasion' above). Therefore, resistance is assessed as '**Low**' based on the potential mortality from direct contact with fishing gear or as bycatch. However, resilience is probably '**High**' so 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

*Ophiura ophiura* is a sediment generalist recorded from silty mud, fine to very fine muddy sand, sandy mud,

clean fine sands, gravels and broken shells (Connor *et al.*, 2004; Boos & Franke, 2006; Boos *et al.*, 2010 Tillin & Tyler-Walters, 2014b), while this biotope (SS.SSa.CMuSa.Ooph) is recorded from muddy sands (JNCC, 2022). Schäfer (1972) noted that brittlestars were usually free from areas of frequent sedimentation but often preserved by rapid sedimentation events and burial (see smothering below). However, no direct evidence of the effects of suspended sediment on *Ophiura ophiura* was found. *Ophiura ophiura* is an omnivore, active predator, scavenger, and detritivore and is not dependent on suspended sediment for its food supply. Therefore, resistance is assessed as '**High**' but with Low confidence. Hence, resilience is '**High**' and sensitivity is assessed as '**Not sensitive**'.

#### Smothering and siltation rate changes (light)

**Medium**

Q: High A: High C: Medium

**High**

Q: Medium A: Medium C: Medium

**Low**

Q: Medium A: Medium C: Medium

Lawrence (1996) noted that smothering was the only main cause of mass mortality for fossil echinoderms. Schäfer (1972) noted that brittlestars were usually free from areas of frequent sedimentation but often preserved by rapid sedimentation events and burial, for example, during and after storms. Schäfer (1972) suggested that the sudden deposition of only 5 cm of sediment was enough to immobilize and kill brittlestars. However, experimental studies suggested that *Ophiura ophiura* was resistant of burial (Last *et al.*, 2011; Henrick *et al.*, 2016). In experimental chambers, *Ophiura ophiura* were buried under 2, 5 or 7 cm of fine, medium or coarse sediment. Mortality after burial depended on the depth and duration of burials as well as the sediment type. Mortality was highest after 32 days of burial (18.5%), in the fine sediment (16.7%) and at 7 cm (22.2%) but was also highest in the largest individuals (6 to 9.7 cm across). However, overall mortality was low (ca 9.9%) due to its ability to emerge from burial. Emergence exceeded 60% in all durations and depths of burial, but was highest in medium sediment (94.4%) and low depths (94.4%) and lowest under coarse sediment (40.7%) decreasing with increasing depth (Last *et al.*, 2011; Henrick *et al.*, 2016).

**Sensitivity assessment.** Last *et al.* (2011) and Henrick *et al.* (2016) concluded that *Ophiura ophiura* was highly tolerant (resistant) of burial under 2-7 cm of fine to coarse sediment for up to 32 days. Therefore, this *Ophiura ophiura* dominated biotope is likely to experience some mortality due to the sudden deposition of 5 cm of fine sediment (the benchmark) and resistance is assessed as '**Medium**' (<25% mortality). Hence, resilience is probably '**High**' and sensitivity is assessed as '**Low**'.

#### Smothering and siltation rate changes (heavy)

**None**

Q: High A: Medium C: Medium

**Medium**

Q: Low A: NR C: NR

**Medium**

Q: Low A: Low C: Low

Lawrence (1996) noted that smothering was the only main cause of mass mortality for fossil echinoderms. Schäfer (1972) noted that brittlestars were usually free from areas of frequent sedimentation but often preserved by rapid sedimentation events and burial, for example, during and after storms. Schäfer (1972) suggested that the sudden deposition of only 5 cm of sediment was enough to immobilize and kill brittlestars. However, experimental studies suggested that *Ophiura ophiura* was resistant of burial (Last *et al.*, 2011; Henrick *et al.*, 2016). In experimental chambers, *Ophiura ophiura* were buried under 2, 5 or 7 cm of fine, medium or coarse sediment. Mortality after burial depended on the depth and duration of burials as well as the sediment type. Mortality was highest after 32 days of burial (18.5%), in the fine sediment (16.7%) and at 7 cm (22.2%) but was also highest in the largest individuals (6 to 9.7 cm across). However, overall mortality was low (ca 9.9%) due to its ability to emerge from burial. Emergence exceeded 60% in all durations and depths of burial, but was highest in medium sediment (94.4%) and low depths (94.4%) and lowest under coarse sediment (40.7%) decreasing with increasing depth (Last *et al.*, 2011; Henrick *et al.*, 2016).

**Sensitivity assessment.** Last *et al.* (2011) and Henrick *et al.* (2016) concluded that *Ophiura ophiura* was highly tolerant (resistant) of burial under 2-7 cm of fine to coarse sediment for up to 32 days. However, the sudden deposition of 30 cm of fine sediment (the benchmark) is likely to be more damaging. Therefore, this *Ophiura ophiura* dominated biotope is likely to experience significant mortality and resistance is assessed as



'None' based on evidence from palaeoecology (Schäfer, 1972). Nevertheless, resilience is probably 'Medium' and sensitivity is assessed as 'Medium'.

<b>Litter</b>	<b>Not Assessed (NA)</b> Q: NR A: NR C: NR	<b>Not assessed (NA)</b> Q: NR A: NR C: NR	<b>Not assessed (NA)</b> Q: NR A: NR C: NR
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No evidence was found and no assessment was made.

<b>Electromagnetic changes</b>	<b>No evidence (NEv)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>No evidence (NEv)</b> Q: NR A: NR C: NR
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No evidence was found

<b>Underwater noise changes</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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*Ophiura* spp. probably reacts to vibration but is unlikely to respond to noise as defined by the benchmark.

<b>Introduction of light or shading</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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Fell (1966) noted that brittlestars were negatively phototactic and avoided visual predators by taking shelter under stones, in crevices or hollows, burrowing or using cryptic colouration. Moore & Cobb (1985) reported that *Ophiura ophiura* immediately 'freeze' any movement in response to shading but that this response was overridden by the presence of food. Sköld (1985) reported that approaching *Ophiura ophiura* with the plan of the hand, without contact, was enough to elicit a phototactic escape response. Therefore, a phototactic response to shading is probably a response to a potential predator. Sköld (1985) and Boos *et al.* (2010) noted that *Ophiura ophiura* did not avoid predators by burrowing but rather rapidly escaped across the substratum surface, except in aquaria where other *Ophiura ophiura* were consumed by fish and predation was intense, in which case they did burrow (Sköld, 1985). However, shading or illumination of this biotope is unlikely to have any negative effects, especially at depth and the pressure is assessed as 'Not relevant'.

<b>Barrier to species movement</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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**Not relevant.** This pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit the dispersal of larvae but larval dispersal is not considered under the pressure definition and benchmark.

<b>Death or injury by collision</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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**Not relevant** to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion'.

<b>Visual disturbance</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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Fell (1966) noted that brittlestars were negatively phototactic and avoided visual predators by taking shelter under stones, in crevices or hollows, burrowing or using cryptic colouration. Moore & Cobb (1985)

reported that *Ophiura ophiura* immediately 'freeze' any movement in response to shading but that this response was overridden by the presence of food. Sköld (1985) reported that approaching *Ophiura ophiura* with the plan of the hand, without contact, was enough to elicit a phototactic escape response. Therefore, a phototactic response to shading is probably a response to a potential predator. Sköld (1985) and Boos *et al.* (2010) noted that *Ophiura ophiura* did not avoid predators by burrowing but rather rapidly escaped across the substratum surface, except in aquaria where other *Ophiura ophiura* were consumed by fish and predation was intense, in which case they did burrow (Sköld, 1985). Therefore, short-range visual disturbance due to the presence of a potential predator or from the hands of divers may be expected to elicit an escape response. However, their visual range is probably very limited and visual disturbance from passing machinery, vessels or boats is unlikely to be relevant.

## Biological Pressures

	Resistance	Resilience	Sensitivity
<b>Genetic modification &amp; translocation of indigenous species</b>	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

No evidence was found to suggest that *Ophiura ophiura* is translocated or subject to genetic modification. Therefore, this pressure is assessed as '**Not relevant**'.

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

The American slipper limpet *Crepidula fornicata* was introduced to the UK and Europe in the 1870s from the Atlantic coasts of North America with imports of the eastern oyster *Crassostrea virginica*. It was recorded in Liverpool in 1870 and the Essex coast in 1887-1890. It has spread through expansion and introductions along the full extent of the English Channel and into the European mainland (Blanchard, 1997, 2009; Bohn *et al.*, 2012, 2013a, 2013b, 2015; De Montaudouin *et al.*, 2018; Helmer *et al.*, 2019; Hinz *et al.*, 2011; McNeill *et al.*, 2010; Powell-Jennings & Calloway, 2018; Preston *et al.*, 2020; Stiger-Pouvreau & Thouzeau, 2015).

*Crepidula fornicata* is recorded from shallow, sheltered bays, lagoons and estuaries or the sheltered sides of islands, in variable salinity (18 to 40) although it prefers ca 30 (Tillin *et al.*, 2020). Larvae require hard substrata for settlement. It prefers muddy gravelly, shell-rich, substrata that include gravel, or shells of other *Crepidula*, or other species e.g., oysters, and mussels. It is highly gregarious and seeks out adult shells for settlement, forming characteristic 'stacks' of adults. But it also recorded in a wide variety of habitats including clean sands, artificial substrata, *Sabellaria alveolata* reefs and areas subject to moderately strong tidal streams (Blanchard, 1997, 2009; Bohn *et al.*, 2012, 2013a, 2013b, 2015; De Montaudouin *et al.*, 2018; Hinz *et al.*, 2011; Powell-Jennings & Calloway, 2018; Preston *et al.*, 2020; Stiger-Pouvreau & Thouzeau, 2015; Tillin *et al.*, 2020).

High densities of *Crepidula fornicata* cause ecological impacts on sedimentary habitats. The species can form dense carpets that can smother the seabed in shallow bays, changing and modifying the habitat structure. At high densities, the species physically smothers the sediment, and the resultant build-up of silt, pseudofaeces, and faeces is deposited and trapped within the bed (Tillin *et al.*, 2020, Fitzgerald, 2007, Blanchard, 2009, Stiger-Pouvreau & Thouzeau, 2015). The biodeposition rates of *Crepidula* are extremely high and once deposited, form an anoxic mud, making the environment suitable for other species, including most infauna (Stiger-Pouvreau & Thouzeau, 2015, Blanchard, 2009). For example, in fine sands, the community is replaced by a reef of slipper limpets, that provide hard substrata for sessile suspension-feeders (e.g., sea squirts, tube worms and fixed shellfish), while mobile carnivorous microfauna occupy species between or within shells, resulting in a homogeneous *Crepidula* dominated habitat (Blanchard, 2009). Blanchard (2009) suggested the transition occurred and became irreversible at 50% cover of the

limpet. De Montaudouin *et al.* (2018) suggested that homogenization occurred above a threshold of 20-50 *Crepidula* /m<sup>2</sup>.

Impacts on the structure of benthic communities will depend on the type of habitat that *Crepidula* colonizes. De Montaudouin & Sauriau (1999) reported that in muddy sediment dominated by deposit-feeders, species richness, abundance and biomass increased in the presence of high densities of *Crepidula* (ca 562 to 4772 ind./m<sup>2</sup>), in the Bay of Marennes-Oléron, presumably because the *Crepidula* bed provided hard substrata in an otherwise sedimentary habitat. In medium sands, *Crepidula* density was moderate (330-1300 ind./m<sup>2</sup>) but there was no significant difference between communities in the presence of *Crepidula*. Intertidal coarse sediment was less suitable for *Crepidula* with only moderate or low abundances (11 ind./m<sup>2</sup>) and its presence did not affect the abundance or diversity of macrofauna. However, there was a higher abundance of suspension-feeders and mobile Crustacea in the absence of *Crepidula* (De Montaudouin & Sauriau, 1999). The presence of *Crepidula* as an ecosystem engineer has created a range of new niche habitats, reducing biodiversity as it modifies habitats (Fitzgerald, 2007). De Montaudouin *et al.* (1999) concluded that *Crepidula* did not influence macroinvertebrate diversity or density significantly under experimental conditions, on fine sands in Arcachon Bay, France. De Montaudouin *et al.* (2018) noted that the limpet reef increased the species diversity in the bed, but homogenised diversity compared to areas where the limpets were absent. In the Milford Haven Waterway (MHW), the highest densities of *Crepidula* were found in areas of sediment with hard substrata, e.g., mixed fine sediment with shell or gravel or both (grain sizes 16-256 mm) but, while *Crepidula* density increased as gravel cover increased in the subtidal, the reverse was found in the intertidal (Bohn *et al.*, 2015). Bohn *et al.* (2015) suggested that high densities of *Crepidula* in high-energy environments were possible in the subtidal but not the intertidal, suggesting the availability of this substratum type is beneficial for its establishment. Hinz *et al.* (2011) reported a substantial increase in the occurrence of *Crepidula* off the Isle of Wight, between 1958 and 2006, at a depth of ca 60 m, on hard substrata (gravel, cobbles, and boulders), swept by strong tidal streams. Presumably, *Crepidula* is more tolerant of tidal flow than the oscillatory flow caused by wave action which may be less suitable (Tillin *et al.*, 2020).

The availability of hard substrata (e.g., gravel) may only restrict initial colonization as higher densities of *Crepidula* function as substrata for subsequent colonization (Thieltges *et al.*, 2004; Blanchard, 2009). However, Bohn *et al.* (2015) noted that *Crepidula* occurred at low density or was absent in areas of homogenous fine sediment and areas dominated by boulders. Bohn *et al.* (2015) suggested that wave action (exposure) probably prevented the establishment of large numbers of *Crepidula* in high-energy areas. Blanchard (2009) noted that sandy areas in the Bay of Saint-Mont Michel were not colonized by *Crepidula* because of surface sand mobility. Thieltges *et al.* (2003) also noted that storm events removed some clumps of mussels and presumably *Crepidula* onto tidal flats where they disappeared, which caused their abundance to fluctuate. Similarly, *Crepidula* was absent from sandy substrata in Swansea Bay but was most abundant in the shelter of the breakwater at the Swansea east site (Powell-Jennings & Calloway, 2018). Powell-Jennings & Calloway (2018) noted that *Crepidula* is killed by sudden burial and possibly burial due to deposition, which could mitigate *Crepidula* density.

**Sensitivity assessment.** The sediments characterizing this biotope are likely to be unsuitable for most of the invasive non-indigenous species currently recorded in the UK. However, the above evidence also suggests that mud and fine sediments are unsuitable for the colonization of *Crepidula fornicata* due to the lack of gravel, shells, or any other hard substrata used for larvae settlement (Bohn *et al.*, 2015; Tillin *et al.*, 2020). This biotope is exposed to wave action and the resultant sediment mobility may also prevent colonization by *Crepidula*. In addition, *Ophiura ophiura* is an omnivore, feeding on a range of other species, including their larvae. It is unlikely that *Crepidula* larvae will survive settlement in this habitat due to the presumed high level of larval predation by the high density of the *Ophiura ophiura*. Therefore, this resistance to colonization by *Crepidula* is assessed as '**High**', resistance as '**High**', and sensitivity as '**Not sensitive**'. However, *Crepidula* has not yet been reported to occur in this biotope so the confidence in the assessment is 'Low' and further evidence is required.

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

*Ophiura ophiura* is associated with the parasitic copepod *Parartotrogus richardi* (Mortensen, 1927; Southward & Campbell, 2006). Mortensen (1927) reported that *Ophiura ophiura* (as *texturata*) was infested with the parasitic green alga *Coccomyxa ophiurae* in the Limfjord. The alga dissolves the brittlestar's skeleton, presumably leading to death (Mortensen, 1927). Any parasitic infestation/disease may result in some mortality within the population. Therefore, resistance is assessed as '**Medium**' based on limited evidence. Hence, resilience is '**High**' and sensitivity is assessed as '**Low**' but with 'Low' confidence.

**Removal of target 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**

*Ophiura ophiura* is not subject to a targetted fishery. Hence, this pressure is '**Not relevant**' in this biotope.

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

*Ophiura* spp. are often removed as bycatch. Bergman & Van Santbrink (2000b) examined the effect of different types of beam trawls and otter trawls in sandy sediments in the Dutch North Sea. They reported that megafauna (>1 cm) experienced annual fishing mortality of 5-35% mainly due to the direct impact of the trawl on the trawl track or indirectly due to disturbance and predation. In particular, *Ophiura ophiura* experienced between 2 and 12% mortality but there were no significant differences between trawl types examined. Bergman & Van Santbrink (2000b) reported that *Ophiura ophiura* experienced a 7% mortality, across all trawl fisheries in 1994 in the Dutch sector of the North Sea. Bradshaw *et al.* (2000) noted that animals with hard tests, e.g. brittlestars such as *Ophiura* spp. were badly damaged by contact with scallop dredges or beam trawls, although they also reported that the abundance of *Ophiura albida* increased in dredge tracks. Bergman & Hup (1992) reported that the number of small *Ophiura* (0.1-0.4 cm) in the surface sediment did not change after three-fold experimental trawling, probably because they escaped undamaged through meshes. Hinz *et al.* (2012) also reported significant negative effects of queen dredges (for scallops) on *Ophiura ophiura* in the dredge tracks. The significant differences between the two types of queen dredge were not seen in bycatch but in the tracks, which suggested the effect was due to the direct impact of the dredges used. Smith *et al.* (2000) noted that epifaunal abundance was reduced in otter-trawl tracks during the trawling season (October-March) in the Mediterranean but increased again after the trawling season.

Constantino *et al.* (2009) examined the effect of clam dredging on the sediment community at different depths. At 18 m that noted that *Ophiura ophiura* was removed from dredge tracks directly after trawling but had returned within 1 day and were present at least 96 days after trawling. However, as scavengers *Ophiura ophiura* may be expected to be attracted to discards and injured organisms in the path of fishing gear. Kaiser & Spencer (1995) reported that 96% of *Ophiura ophiura* bycatch were alive after experimental trawling with a 4 m beam trawl but that mortality increased to 19% after 120 hours. Mortality was due to >50% damage to the disc (Kaiser & Spencer, 1995). Bergmann & Moore (2001b) reported 100% mortality in the *Ophiura ophiura* brought onboard as bycatch 14 days after trawling and aerial exposure and high mortality (91%) in specimens returned to the water immediately after trawling. They concluded that earlier studies underestimated mortality because they only monitored mortality for up to five days.

Rumohr & Kujawski (2000) compared historical data on epifauna in the southern North Sea from 1900-1912 with data from 1986. They noted that bivalve populations had declined while scavengers and predators (sea stars, crustaceans and gastropods) have increased in frequency due to the effects of fishing activities. However, they reported that *Ophiura ophiura* was absent from their stations in 1986 but had occurred in 55% of stations in 1900-1912, while other *Ophiura* spp. had increased in frequency. Bradshaw *et al.* (2002) reported that *Ophiura albida* was one of a number of species that increased in abundance over a

60-year period from ca 1939 and 1950 to 1994 in areas of the Irish Sea subject to scallop dredging. They suggested that the life-history characteristics of *Ophiura* spp. (mobility and good regeneration from non-fatal injuries) provided resilience against the long-term impacts of trawling. Callaway *et al.* (2007) reported that *Ophiura ophiura* was one of 12 species to double their spatial presence (distribution) in the North Sea from 1902 to 2000, in spite of fishing activity.

**Sensitivity assessment.** In their summary, Bergmann & Moore (2001b) noted that while some studies concluded that *Ophiura ophiura* was resilient to fishing gear due to their high capacity for regeneration and some studies had found a significant increase in *Ophiura ophiura* densities after experimental trawling, other studies had shown a significant reduction in ophiuroid densities due to fishing disturbance. They concluded that the species continued abundance in the Clyde Sea suggested that populations exposed to trawling could be restocked from adjacent populations and that brittlestar mortality from trawling could be outweighed by the species' reproductive resilience and the possible reduction in the density of its predators or competitors by fishing activities (Bergmann & Moore, 2001b). Therefore, resistance is assessed as '**Low**' based on the potential mortality from direct contact with fishing gear or as bycatch. However, resilience is probably '**High**' so sensitivity is assessed as '**Low**'.

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