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Ostrea edulis beds on shallow sublittoral muddy mixed sediment

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

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Ostrea edulis beds on shallow sublittoral muddy sediment.
 Photographer: Bernard Picton
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Researched by Frances Perry & Dr Harvey Tyler-Walters

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A5.435	<i>Ostrea edulis</i> beds on shallow sublittoral muddy mixed sediment
JNCC 2015	SS.SMx.IMx.Ost	<i>Ostrea edulis</i> beds on shallow sublittoral muddy mixed sediment
JNCC 2004	SS.SMx.IMx.Ost	<i>Ostrea edulis</i> beds on shallow sublittoral muddy mixed sediment
1997 Biotope	SS.IMX.Oy.Ost	<i>Ostrea edulis</i> beds on shallow sublittoral muddy sediment

🔍 Description

Dense beds of the oyster *Ostrea edulis* can occur on shallow sublittoral muddy fine sand or sandy mud mixed sediments. There may be considerable quantities of dead oyster shell making up a substantial portion of the substratum. The clumps of dead shells and oysters can support large numbers of *Ascidella aspersa* and *Ascidella scabra*. Sponges such as *Halichondria bowerbanki* may also be present. Several conspicuously large polychaetes, such as *Chaetopterus variopedatus* and terebellids, as well as additional suspension-feeding polychaetes such as *Myxicola infundibulum* and

Sabella pavonina may be important in distinguishing this biotope, whilst the opisthobranch *Philine quadripartita* may also be frequent in some areas. A turf of seaweeds such as *Plocamium cartilagineum*, *Nitophyllum punctatum* and *Spyridia filamentosa* may also be present. This biotope description may need expansion to account for oyster beds in England. (Information from Connor *et al.*, 2004; JNCC, 2015).

↓ Depth range

0-5 m, 5-10 m, 10-20 m

Additional information

The native, flat oyster (*Ostrea edulis*) has been extensively studied due to its commercial importance. Therefore, this review is based on past reviews, to which the reader should refer to further detail (e.g. Korringa, 1952; Yonge, 1960). Dr Cass Bromly, peer-reviewed the sensitivity assessments and

✓ Listed By

- none -

Further information sources

Search on:



Habitat review

🔄 Ecology

Ecological and functional relationships

Oyster beds are dominated by suspension feeding invertebrates.

- *Ostrea edulis* is an active suspension feeder on phytoplankton, bacteria, particulate detritus and dissolved organic matter (DOM) (Korringa, 1952; Yonge, 1960). The production of faeces and pseudofaeces enriches the underlying sediment, providing a rich food source for infauna detritivores, deposit feeders, meiofauna and bacteria.
- Dense beds of suspension feeding bivalves are important in nutrient cycling in estuarine and coastal ecosystems, transferring phytoplankton primary production and nutrients to benthic secondary production (pelagic-benthic coupling) (Dame, 1996).
- A model food web for an oyster reef (based on intertidal *Crassostrea* sp. beds) was presented by Dame (1996).
- Other suspension feeding epifauna include the ascidians (e.g. *Asciella aspersa*, *Asciella scabra* and *Dendrodoa grossularia*) and sponges (e.g. *Halichondria bowerbanki*), hydroids, barnacles (e.g. *Balanus balanus*), and tube worms such as *Spirobranchus triqueter* and *Polydora ciliata*.
- Infaunal suspension feeders include the tube worms *Chaetopterus variopedatus*, *Sabella pavonina*, *Myxicola infundibulum*, and *Lanice conchilega* and where present *Abra* sp. and the tellinids *Macomangulus tenuis* and *Fabulina fabula*.
- *Lanice conchilega*, *Fabulina fabula* and *Polydora ciliata* are also surface deposit feeders on organic particulates and detritus.
- The enriched sediment probably supports a diverse meiofauna, including nematodes and polychaetes (e.g. *Scoloplos armiger* and terebellids).
- The sediment may also support amphipods such as *Bathyporeia guilliamsoniana* and *Ampelisca brevicornis*, which have been recorded in native oyster beds (Millar, 1961).
- Hermit crabs such as *Pagurus bernhardus* and the common whelk *Buccinum undatum* may be scavengers on the bed.

A variety of predators feed in oyster beds.

- *Asterias rubens* is a general predator occasionally taking oyster spat and oysters but with a preference for mussels and, in their absence, *Crepidula fornicata* and the American oyster drill *Urosalpinx cinerea*. Young *Asterias rubens* feeds on barnacles in preference to oyster spat (Hancock, 1955). Hancock (1955) suggested that *Asterias rubens* fed significantly more on predators and competitors of the native oyster than on the oysters themselves. However, he also noted that the starfish was still likely to cause severe damage on highly cultivated areas with a high abundance of oysters and their spat. *Asterias rubens* is itself preyed on by the sun star *Crossaster papposus* (Hancock, 1958).
- Predatory gastropods such as the native Sting winkle *Ocenebra erinacea* and the introduced American oyster drill *Urosalpinx cinerea* prey on small oysters and oyster spat. For example, 55 -58% of the oyster spat settling in 1953 in Essex oyster beds were destroyed by *Urosalpinx cinerea*. The dog whelk *Nucella lapillus* may occasionally take oyster spat (Korringa, 1952; Hancock, 1954; Yonge, 1960). However, only 10% of adults of 3 years of age were taken by *Urosalpinx cinerea* (Hancock, 1954), suggesting that the risk of predation decreases with increasing oyster size. A similar size refuge from

predation is seen in other bivalve beds e.g. *Mytilus edulis* and the horse mussel *Modiolus modiolus*.

- Crabs, such as *Carcinus maenas* and *Hyas araneus* are mobile omnivores that prey on oysters and their spat and also on the other fauna associated with oyster beds, including the drills, whelks and starfish (Yonge, 1960).
- Predatory fish may also enter the bed to feed on the associated species, although Yonge (1960) suggested that fish were not a significant predator of the oysters themselves.

Several species compete with the oyster spat for settlement space on the shells of adult oysters, especially those species that breed at the same time of the year.

- *Asciidiella* sp. are known to settle at the same time as oyster spat, competing for the available hard substratum such as oyster shells (living or dead), and subsequently overgrowing spat that are able to settle. However, this may only seriously affect the oyster recruitment where the ascidians occur in any abundance.
- Barnacles (e.g. *Balanus balanus* and *Eliminius modestus*), the tube worm *Spirobranchus triqueter* and the ascidian *Dendrodoa grossularia* were also reported to compete for settlement space, especially the barnacles (Korringa, 1952; Yonge, 1960; Millar, 1961).
- The introduced slipper limpet *Crepidula fornicata* competes with the oyster for space and food, and its pseudofaeces may smother the oyster. Where *Crepidula fornicata* has become abundant the oyster beds have been lost (see sensitivity to introduced species) (Blanchard, 1997).

Seasonal and longer term change

Fish and crabs predators probably migrate further offshore in winter months, reducing predation pressure. Changes in the average summer temperature may have significant effects on recruitment (see recruitment processes below). In addition, Spärck (1951) noted marked changes in the populations of *Ostrea edulis* in the Limfjord, Denmark between 1852 and 1949. In periods of poor recruitment and the absence of fishing pressure, populations gradually declined, becoming restricted to the most favourable areas of the Limfjord. In some areas there was a 90% decrease in stock. Temperature was probably the most important controlling factor in recruitment in the Limfjord population (see recruitment) (Spärck, 1951). Korringa (1952) noted that while temperature was probably the most important factor in populations at their northern most range of the species, other factors were important in more temperate waters. However, Spärck (1951) demonstrated the importance of recruitment in natural populations of the native oyster and the potential for large fluctuations in population size over time.

Habitat structure and complexity

Oyster beds provide hard substratum for settlement in an otherwise sedimentary habitat and therefore support a diverse range of invertebrates. The oyster bed also modifies the sediment, increasing the amount of shell debris and organically enriching the sediment with faeces and pseudofaeces. *Ostrea edulis* preferentially settles on adult of the same species (i.e. it is gregarious) resulting in layer upon layer of oysters in the absence of fishing pressure. The layer of living and dead oyster shell probably alters the water flowing over the sediment surface and protects it from erosion. The layers of shell debris and living oyster provide interstices for other organisms. For example, the American oyster *Crassostrea virginica* can form extensive reefs several metres in height that have been shown to affect the local hydrodynamics and hence larval dispersal and settlement and hence community composition (Lenihan, 1999; Peterson *et al.*, 2000). While, no

information concerning the scale of native oyster reefs was found, it is likely that they also affect the local hydrographic regime to some extent.

- Oyster beds support a diverse epifauna consisting of protozoa, sponges, hydroids, the benthic stages of *Aurelia* sp., flatworms, ribbon worms, nematodes polychaetes, amphipods and ostracod crustaceans, crabs, sea spiders, gastropod molluscs, ascidians, bryozoans, starfish and sea urchins (Korringa, 1951; Yonge, 1960). Korringa (1951) also noted that the flanges or flaps of the oyster shell provided refuges for some species. Although the exact fauna found will depend on locality, a detailed account of the epifauna of oyster beds in the Oosterschelde is given by Korringa (1951).
- The sediment surface may be punctuated by burrowing tube worms such as *Chaetopterus variopedatus*, *Sabella pavonina*, *Myxicola infundibulum*, and *Lanice conchilega*.
- Burrowing amphipods may occupy the top few cm of the sediment e.g. *Bathyporeia guilliamsoniana* and *Ampelisca brevicornis*.
- The sediment below the oyster bed is enriched by faeces and pseudofaeces and usually contains shell debris accumulated from dead oysters. The infauna will vary with nature of the underlying sediment and the relative proportions of shell debris and faecal deposits. However, macroinfauna probably includes burrowing polychaetes, nematodes, and bivalves (see ecological relationships above).

Productivity

Dame (1996) suggested that dense beds of bivalve suspension feeders increase turnover of nutrients and organic carbon in estuarine (and presumably coastal) environments by effectively transferring pelagic phytoplanktonic primary production to secondary production in the sediments (pelagic-benthic coupling). Increased microbial activity within the enriched sediments underlying the beds, increases the rate of nutrient turnover and hence the productivity of the ecosystem as a whole (Dame, 1996).

Epifloral macroalgae provide some primary productivity to the ecosystem, however, the majority of production with the biotope is secondary production, with organic carbon derived from phytoplankton and organic particulates consumed by suspension feeders, especially the oysters. No estimate of the overall productivity of native oyster beds was found. However, before over-fishing and disease (see importance) oysters beds supported fisheries, suggesting that there are potentially highly productive.

Recruitment processes

The flat oyster

In *Ostrea edulis*, spawning occurs in the summer months (June to September) and is coincident with spring tides (and the new or full moon) (Korringa, 1952; Yonge, 1960). Spawning is thought to require a minimum temperature (which also probably controls gametogenesis) of 15-16°C (Yonge, 1960) although the exact temperature probably varies with area and local adaptation (Korringa, 1952). Eggs are fertilized internally and incubated to the veliger stage (7-10 days) at which point they are released into the plankton.

Ostrea edulis is highly fecund producing an average of between 91,000 to up to 2 million eggs with increasing age and size. However, good fertilization efficiency requires a minimum population size, so that in small populations not all the eggs may be fertilized (Spärck, 1951). The larvae are pelagic for 11-30 days, providing potentially high levels of dispersal, depending on the local hydrographic regime. Subsequent recruitment however, is dependant on larval growth and mortality due to

predation in the plankton, the availability of settlement sites and post-settlement and juvenile mortality.

Good recruitment (settlement) is associated with warm summers whereas poor recruitment occurred in cold summers in the Oosterschelde and Limfjord (Spärck, 1951; Korringa, 1952), and is probably related to larval food availability and developmental time. Widdows (1991) states that any environmental or genetic factor that reduces the rate of growth or development of *Mytilus edulis* larvae will increase the time spent in the plankton and hence significantly decrease larval survival, which may also be true of most pelagic bivalve larvae.

In areas of strong currents larvae may be swept away from the adult populations to other oyster beds or to areas of unsuitable substratum and lost. Oyster beds on open coasts may be dependent on recruitment from other areas. Oyster beds in enclosed embayments may be self recruiting. Due to the high numbers of larvae produced, a single good recruitment event could potentially significantly increase the population. Oyster larvae will settle on available hard substrata but are gregarious and prefer to settle on adult shells, especially the new growth. However, competition for space (substratum for settlement) from other species that settle at the same time of year e.g. barnacles and ascidians (see ecological relationships), results in high levels of larval and juvenile mortality. Newly settled *Ascidella* sp., are known to overgrow and hence kill oyster larvae. In addition, newly settled spat and juveniles are subject to intense mortality due to predation, especially by the oyster drills (*Urosalpinx cinerea* and *Ocenebra erinacea*) and starfish. For example, in the Oosterschelde, Korringa (1952) reported 90% mortality in oyster spat by their first winter, with up to 75% being taken by *Urosalpinx cinerea*, while Hancock (1955) noted that 73% of spat settling in summer 1953 died by December, 55 -58% being taken by *Urosalpinx cinerea*.

Overall, recruitment in *Ostrea edulis* is sporadic and dependant of local environmental conditions, including the average summer sea water temperature, predation intensity and the hydrographic regime. Spärck, (1951) reported marked changes in population size due to recruitment failure. In unfavourable year stocks declined naturally (in the absence of fishing pressure) and the population in the Limfjord became restricted to the most favourable sites. In favourable years the stock increased and the population slowly spread from the most favoured locations. However, he concluded that a long series of favourable years was required for recovery of stocks after depletion. For example, after closure of the oyster fishery in 1925, stocks did not recover their fishery potential until 1947/48, ca 20 years. However, the Limfjord population of *Ostrea edulis* is at the northern most extent of its range where recruitment may be more dependant on summer temperatures than more southerly temperate populations. Nevertheless, Spärck's data (1951) suggest that several years of favourable recruitment would be required for an *Ostrea edulis* population to recover.

Other species

The other characterizing species are widespread species, with pelagic larvae, potentially capable of wide dispersal and are therefore, likely to be able to recolonize available substratum rapidly. Although the ascidian tadpole larva is short lived and has a low dispersal capability, fertilization is external in the most conspicuous ascidians in the biotope, *Ascidella* sp., which are widespread in distribution and probably capable of rapid recolonization from adjacent or nearby populations.

Time for community to reach maturity

Korringa (1951) noted that many of the *Ostrea edulis* epifauna were dependant on the oyster for substratum. It is also likely that some burrowing species are dependant of the conditions provided

by the bed of *Ostrea edulis*. Therefore, the time taken for the community to reach maturity will depend primarily on the time taken for the oyster bed to develop (see recruitment processes above), after which recolonization will probably be rapid, and in the order of 1-2 years.

Additional information

No text entered

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m, 10-20 m
Water clarity preferences	
Limiting Nutrients	
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	Estuary, Sea loch / Sea lough
Biological zone preferences	Infralittoral, Lower circalittoral, Lower infralittoral, Sublittoral
Substratum/habitat preferences	Cobbles, Gravel / shingle, Large to very large boulders, Mixed, Pebbles, Sandy gravel, Sandy mud, Small boulders
Tidal strength preferences	Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Sheltered, Very sheltered
Other preferences	

Additional Information

The main UK shellfish stocks of the native oyster are now located in the inlets and flats bordering the Thames Estuary, The Solent, River Fal, the west coast of Scotland and Lough Foyle (Anon, 1999c).

Species composition

Species found especially in this biotope

- [Asciidiella aspersa](#)
- [Ostrea edulis](#)

Rare or scarce species associated with this biotope

-

Additional information

The MNCR recorded a total of 246 species within this biotope, although not all occurred in a single record. Studies of the fauna of native oyster have been reported for the Oosterschelde (Korringa,

1951), Scottish waters (Millar, 1961), Loch Ryan (Millar, 1963; Howson *et al.*, 1994); and the Essex oyster beds (Mistakidis, 1951). Korringa (1951) listed over 250 species of epifauna on the shells of [Ostrea edulis](#) in the Oosterschelde.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The description of this biotope and information on the characterizing species is taken from Connor *et al.*, (2004). This biotope, SS.SMx.IMx.Ost, describes dense native oyster beds from 0 – 20 m on muddy sand and mixed substrate where large amounts of dead oyster shell are often present. The native oyster, *Ostrea edulis*, settles in groups, preferring to settle on an adult of the same species, resulting in layers of oysters. Layers of oysters form beds, providing substratum and interstices for a diversity of other organisms. Accumulation of shell material, faeces and pseudofaeces further modify and enrich the sediment. Other species known to occur within the biotope include ascidians, large polychaetes and sponges. A turf of seaweeds may also be present (Connor *et al.*, 2004). The other species that contribute to the biotope have a widespread distribution and take advantage of the substratum or stabilized sediment provided by the population of *Ostrea edulis*. The ascidians *Ascidella aspersa* and *Ascidella scabra* are commonly found on oyster beds but are generally regarded as a competitor with the oysters and their presence is not restricted to this biotope. A number of marine worms are found within this biotope, one of the most frequently found and most notable is the filter feeding parchment worm, *Chaetopterus variopedatus*. The shallow nature of this biotope allows a number of macroalgae to attach to the hard substrata formed by the *Ostrea edulis*. Only *Ostrea edulis* has been chosen to indicate the sensitivity of the biotope. Loss or damage of this ecosystem engineering species will affect the biotope as a whole, and can determine if the biotope remains in any form.

Resilience and recovery rates of habitat

The native oyster, *Ostrea edulis*, occurs naturally from Norway to the Mediterranean, from the low intertidal into water depths of about 80 m. *Ostrea edulis* were once very common around the coast but they have now virtually disappeared from the intertidal and shallow sublittoral because of over-exploitation, habitat damage and disease. In some areas there may be a small amount of natural settlement onto the lower shore of introduced species of oyster. Most populations are now artificially laid for culture and protected by Protection Orders (Fowler, 1999; taken from Tillin & Hull, 2013f). Dense beds of the oyster *Ostrea edulis* occur from the low intertidal shore down into the sublittoral. This species is found on a range of substrata; firm bottoms of mud, rocks, muddy sand, muddy gravel with shells and hard silt (Tillin & Hull, 2013f). Native oyster beds are sparsely distributed around the UK and Ireland and are recorded from Strangford Lough, Lough Foyle and the west coast of Ireland, Loch Ryan in Scotland, Milford Haven in Wales, and from Dawlish Warren, the Dart Estuary and the River Fal in the south west England, and the River Crouch in east England (Tyler-Walters, 2008).

The lifespan of *Ostrea edulis* is considered to be between 5-10 years (Roberts *et al.*, 2010), with individuals first becoming sexually mature between 3 and 5 years. *Ostrea edulis* adults are cemented to the substratum, adult immigration is not possible and recovery is dependent on the larval phase. Recovery of *Ostrea edulis* populations is dependent on larval recruitment, since newly settled juveniles and adults cement themselves to the substratum and are subsequently incapable of migration. Recruitment in *Ostrea edulis* is sporadic and dependent on local environmental conditions, including the average summer seawater temperature, predation intensity and the hydrographic regime. Spawning is thought to require a minimum temperature (which also probably controls gametogenesis) of 15-16°C (Yonge, 1960) although the exact temperature probably varies with area and local adaptation (Korringa, 1952). Eggs are fertilized internally and incubated to the veliger stage (7-10 days) at which point they are released into the plankton.

Ostrea edulis can be highly fecund, producing an average of between 91,000 to up to 2 million eggs. A number which increases with age and size. However, good fertilization efficiency requires a minimum population size, so that in small populations not all the eggs may be fertilized (Spärck, 1951). The size of the sexually mature population and the production of larvae are not accurate ways of predicting the success of spatfall (Gravestock *et al.*, 2014). The larvae are pelagic for 11-30 days, providing potentially high levels of dispersal, depending on the local hydrographic regime. In areas of strong currents larvae may be swept away from the adult populations to other oyster beds. Oyster beds on open coasts may be dependent on recruitment from other areas, oyster beds in enclosed embayments may be self-recruiting. The main determinants of larval settlement are substratum availability, adult abundance, and local environmental conditions and hydrographic regime (Roberts *et al.*, 2010). Oyster settlement is known to be highly sporadic, and spat can suffer mortality of up to 90% (Cole, 1951). This mortality is due to factors including, but not restricted to; temperature, food availability, suitable settlement areas, and the presence of predators (Cole, 1951; Spärck, 1951; Kennedy & Roberts, 1999; Lancaster, 2014). *Ostrea edulis* larvae respond to environmental cues which guide them to settling within the most suitable locations (Walne, 1974; Woolmer *et al.*, 2011). High light levels (1250 lux) and high food concentrations can influence the level of settlement (Bayne, 1969). As can the presence of bacterial films (Fitt *et al.*, 1990 and Tritar *et al.*, 1992; cited in Mesias-Gransbiller *et al.*, 2013). An extremely important chemical cue comes from conspecifics. Bayne (1969) stated that *Ostrea edulis* larvae are highly gregarious and will preferably settle where larvae have previously settled. A number of other studies have also found that larvae select well stocked beds to degraded beds or barren sediment (Cole & Knight-Jones, 1939, 1949; Walne, 1964; Jackson & Wilding 2009; cited in Gravestock, 2014). In addition to live settled oysters, spat will also settle selectively on recently dead oysters Woolmer *et al.*, (2011) and oyster cultch (shell) (Kennedy & Roberts, 1999). Other bivalve cultch can also encourage settlement of oyster spat, although which species of shell is most beneficial to this is debated (Gravestock *et al.*, 2014). Good recruitment is associated with warm summers whereas poor recruitment occurred in cold summers in the Oosterschelde and Limfjord (Spärck, 1951; Korringa, 1952), and is probably related to larval food availability and developmental time. Widdows (1991) states that any environmental or genetic factor that reduces the rate of growth or development of *Mytilus edulis* larvae will increase the time spent in the plankton and hence significantly decrease larval survival, which may also be true of most pelagic bivalve larvae. If populations have been reduced considerably then the standing stock can be insufficient to ensure successful spawning (Tyler-Walters, 2008). *Ostrea edulis* beds are known to have been severely damaged by trawling and may be replaced by deposit feeding polychaetes which may influence the recovery of suspension feeding species (Sewell & Hiscock, 2005; Bergman & van Santbrink, 2000; Gubbay & Knapman, 1999). Hall (2008) also found limited evidence of recovery of stable biogenic reefs to towed bottom fishing gears, with removal or damage to these biotopes reducing complexity and ability to support communities of high biological diversity.

Spärck (1951) reported significant changes in population size due to recruitment failure. In years of bad recruitment stocks declined naturally (in the absence of fishing pressure) and the population in the Limfjord became restricted to the most favourable sites. In years of good recruitment the stock increased and the population increased. Spärck (1951) concluded that a long series of favourable years was required for recovery. After closure of the oyster fishery in Limfjord in 1925, stocks did not recover their fishery potential until 1947/48. However, the Limfjord population of *Ostrea edulis* is at the northern most extent of its range where recruitment may be more dependent on summer temperatures than more southerly temperate populations.

Rees *et al.* (2001) reported that the population of native oysters in the Crouch estuary increased between 1992 -1997, due to the reduction in TBT concentration in the water column.

Nevertheless, Spärck's (1951) data suggest that several years of favourable recruitment would be

required for an *Ostrea edulis* population to recover. Native oyster beds were considered scarce in Europe as early as the 1950s (Korringa, 1952; Yonge, 1960) and are still regarded as scarce today (Connor *et al.*, 1999a).

Following the reduction in oyster populations, re-establishment can be restricted by invasive non-native species. One such species is *Crepidula fornicata*, a species which can become dominant in oyster habitat and restrict recovery through changes to the environment and competition (Blanchard, 1997; Hawkins *et al.*, 2005; Laing *et al.*, 2005; cited in Gravestock *et al.*, 2014). In addition, newly settled spat and juveniles are subject to intense mortality due to predation, especially by the oyster drills (*Urosalpinx cinerea* an invasive non-native species, and *Ocenebra erinacea*) and starfish. For example, in the Oosterschelde, Korringa (1952) reported 90% mortality in oyster spat by their first winter, with up to 75% being taken by *Urosalpinx cinerea*, while Hancock (1955) noted that 73% of spat settling in summer 1953 died by December, 55 -58% being taken by *Urosalpinx cinerea*. Newly settled *Ascidella* sp., are known to overgrow and hence kill oyster larvae.

Resilience assessment. Recovery is likely to be slow even within or from established populations. However, since larvae require hard substratum for settlement with a significant preference for the shells of adults, where the adult population has been removed, especially where shell debris has also been removed. For this reason resilience to a pressure which removes part of the *Ostrea edulis* population is given as 'Low' (10 -25 years for return). For a pressure which entirely removed the population of *Ostrea edulis* the resilience is 'Very low' (>25 years).

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

Hydrological Pressures

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

Filtration rate, metabolic rate, assimilation efficiency and growth rates of adult *Ostrea edulis* increase with temperature. Growth was predicted to be optimal at 17°C or, for short periods, at 25°C (Korringa, 1952; Yonge, 1960; Buxton *et al.*, 1981; Hutchinson & Hawkins, 1992). Hutchinson & Hawkins (1992) noted that temperature and salinity were co-dependent, so that high temperatures and low salinity resulted in marked mortality, no individuals surviving more than 7 days at 16 psu and 25°C, although these conditions rarely occurred in nature. No upper lethal temperature was found, although Kinne (1970) reported that gill tissue activity fell to zero between 40-42°C, although values derived from single tissue studies should be viewed with caution. Buxton *et al.* 1981 reported that specimens survived short-term exposure to 30°C. *Ostrea edulis* and many of the other species in the biotope occur from the Mediterranean to the

Norwegian coast and are unlikely to be adversely affected by long-term changes in temperatures in Britain and Ireland.

Spärck's (1951) data suggest that temperature is an important factor in recruitment of *Ostrea edulis*, especially at the northern extremes of its range and Korringa (1952) reported that warm summers resulted in good recruitment. Spawning is initiated once the temperature has risen to 15-16°C, although local adaptation is likely (Korringa, 1952; Yonge, 1960). Davis & Calabrese (1969) reported that larvae grew faster with increasing temperature and that survival was optimal between from 12.5 - 27.5°C but that survival was poor at 30°C. Therefore, recruitment and the long-term survival of an oyster bed is probably affected by temperature and may benefit from both short and long-term increases.

Most of the other characterizing species within the biotope have a wide distribution in Europe suggesting that they are able tolerate a wider range of temperatures than found in British waters. Delicate species may not be so tolerant and mobile species may leave the biotope temporarily resulting in a decline in species richness.

Sensitivity assessment. Overall biotope resistance to the pressure at the benchmark is assessed as 'High' with a consequent resilience of 'High'. Therefore this biotope is 'Not sensitive' to the pressure at the benchmark level.

Temperature decrease (local)

Medium

Q: High A: High C: Medium

Medium

Q: High A: High C: Medium

Medium

Q: High A: High C: Medium

Hutchinson & Hawkins (1992) suggested that *Ostrea edulis*, the dominant species in this biotope, switched to a reduced, winter metabolic state below 10 °C that enabled it to survive low temperatures and low salinities encountered in shallow coastal waters around Britain. Davis & Calabrese (1969) also noted that larval survival was poor at 10 °C. Korringa (1952) reported that British, Dutch and Danish oysters can withstand 1.5°C for several weeks. However, heavy mortalities of native oyster were reported after the severe winters of 1939/40 (Orton, 1940) and 1962/63 (Waugh, 1964). Mortality was attributed to relaxation of the adductor muscle so that the shell gaped, resulting in increased susceptibility to low salinities or to clogging with silt.

Low temperatures and cold summers are correlated with poor recruitment in *Ostrea edulis*, presumably due to reduced food availability and longer larval developmental time, especially at the northern limits of its range. Therefore, a reduction in temperature may result in reduced recruitment and a greater variation in the populations of *Ostrea edulis*.

The severe winters of 1939/40 and 1962/63 (Orton, 1940; Waugh, 1964) also resulted in the death of associated fauna, e.g. *Sabella pavonina* and other polychaetes died in great numbers, *Crepidula fornicata* incurred about 25% mortality and *Ocenebra erinacea* died in large numbers, while only small *Carcinus maenas* remained on the beds (Orton, 1940; Waugh, 1964). However, starfish, crabs such as *Hyas araneus* and *Urosalpinx cinerea* and *Ascidella aspersa* were little affected (Orton, 1940; Waugh, 1964).

Mobile predatory species found within this biotope, such as fish and crabs, probably migrate further offshore in winter months, reducing predation pressure. Changes in the average summer temperature may have significant effects on recruitment. In addition, Spärck (1951) noted marked changes in the populations of *Ostrea edulis* in the Limfjord, Denmark between 1852 and 1949. In periods of poor recruitment and the absence of fishing pressure, populations gradually declined,

becoming restricted to the most favourable areas of the Limfjord. In some areas there was a 90% decrease in stock. Temperature was probably the most important controlling factor in recruitment in the Limfjord population (Spärck, 1951).

Sensitivity assessment. Decreases in temperature experienced in a severe winter are more extreme than at this pressure benchmark. However, long-term decreases in temperature could potentially effect overall recruitment and other members of the community are intolerant of short-term acute decreases in temperature. Resistance is assessed as 'Medium', and resilience have been assessed as 'Low' which, results in the sensitivity of this biotope being 'Medium' to the pressure at the benchmark.

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

This biotope is found subtidally in full to variable salinity waters and is unlikely to experience increased salinity waters. Hyper-saline effluent may be damaging but no information concerning the effects of increased salinity on oyster beds was found. Therefore an assessment of 'No evidence' is given.

Salinity decrease (local)

Medium

Q: Medium A: Medium C: Medium

Low

Q: High A: High C: Medium

Medium

Q: Medium A: Medium C: Medium

Ostrea edulis is euryhaline and colonizes estuaries and coastal waters exposed to freshwater influence (Yonge, 1960). Yonge (1960) reported that the flat oyster could not withstand salinities below 23 psu. However, Hutchinson & Hawkins (1992) noted that scope for growth was severely affected below 22 psu, probably because the oyster's valves were closed, but that 19 -16 psu could be tolerated if the temperature did not exceed 20°C. At 25°C animals did not survive more than 7 days at 16 psu. Hutchinson & Hawkins (1992) noted that at low temperatures (10°C or less) the metabolic rate was minimal. This may help *Ostrea edulis* survive in low salinities associated with storm runoff.

Several of the characterizing species in this biotope are commonly found in estuarine and full salinity waters and are probably tolerant of reduced salinity, e.g. *Lanice conchilega* and *Ascidella aspersa* will tolerate salinities as low as 18psu (Fish & Fish, 1996). However, this biotope has only been recorded from full salinity habitats, therefore, a proportion of the epifauna and infauna may not tolerate a reduction in salinity and may be lost. Predatory starfish and other echinoderms are generally not able to tolerate low salinity and may be excluded.

Sensitivity assessment. The oyster bed may not be adversely damaged by a decrease in salinity comparable to the benchmark, and can probably tolerate short-term acute reductions in salinity due to runoff. However, a decrease in the salinity regime for a year is likely to have a negative impact on the biotope. There is little evidence to support this, however, records of this biotope being found only in fully marine conditions (Connor *et al.*, 2004) suggests that this biotope would not survive in a variable salinity regime. Therefore, resistance has been assessed as 'Medium' and resilience as 'Low', then a sensitivity of 'Medium' is recorded at the benchmark level. Giving the biotopes a sensitivity of 'Medium' to the pressure at the benchmark.

Water flow (tidal current) changes (local)**High**

Q: Medium A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

This biotope occurs in weak to very weak tidal streams. An increase in water flow above that of the pressure benchmark, for example weak to strong, is likely to remove (erode) fine particulates, leaving coarser substrata and making more hard substratum available for settlement by oysters and other members of the community, e.g. *Ascidrella* sp. and epifauna. An increase in water flow rate could cause oysters to be swept away by strong tidal flow if the substratum to which they are attached is removed. Therefore, a proportion of the oyster bed may be lost, depending on the nature of the substratum.

Increased water flow can affect the ability of oysters to feed. An increase in water flow could reduce the time oysters are able to feed. Yet could improve the availability of suspended particles on which oysters feed. The former is thought to affect the biotope more significantly whilst the latter the individual species. With increased water flow rate the oyster filtration rate increases, up to a point where the oysters are unable to remove more particles from the passing water and thus individual species are likely to benefit from increased water flow rate.

Reproductive success and successful recruitment to an oyster bed may also be affected by a change in water flow. Recruitment is already known to be sporadic and dependent on the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material (Cole, 1951). An increase in water flow rate may interfere with settlement of spat and it is thought that growth rates of *Ostrea edulis* are faster in sheltered sites than exposed locations, although this is thought to be attributed to the seston volume rather than flow speed or food availability (Valero, 2006). Oysters may also be swept away by strong tidal flow if the substratum to which they are attached is removed.

Sensitivity assessment. A change in water flow at the benchmark of this pressure it is highly unlikely that the change will cause any effect on this biotope. However an increase above the benchmark of this pressure could have a negative impact. Both the resilience and resistance of this biotope are assessed as 'High', which results in the biotope being assessed as 'Not sensitive'.

Emergence regime changes**High**

Q: Medium A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

Beds of the native oyster *Ostrea edulis* may occur low on the shore and are exposed for a proportion of the tidal cycle. *Ostrea edulis* is known to be able to survive aerial exposure at low temperatures during storage and are known to be capable of anaerobic respiration (Korringa, 1952; Yonge, 1960), which suggests that they can tolerate aerial exposure. In addition, in the mariculture of oysters (native and introduced species) oyster trays are positioned in the low intertidal, and regularly exposed to the air. Therefore, an increase in desiccation in this biotope, is unlikely to result in death of the oysters themselves at the level of the benchmark. However, exposure to the air prevents feeding, and anaerobic respiration usually results in an oxygen debt, an energetic cost that the organism must make up on return to aerated water, resulting in reduced growth and reproductive capacity.

The associated epifauna may be more intolerant, such as ascidians (e.g. *Ascidrella* spp.) and *Asterias rubens*. Burrowing infauna are likely to be protected from desiccation by their infaunal habit and species such as *Lanice conchilega*, *Myxicola infundibulum* and *Chaetopterus variopedatus* may be

found at low water. Mobile epifaunal species would probably move to deeper water while delicate hydroids and bryozoans may be damaged or killed by desiccation.

This biotope is subtidal so that an increase in emergence is unlikely to have an adverse effect on the community. However, increased emergence may allow the oyster bed to spread further up the shore, although at a slow rate. Therefore, the biotope may benefit from the factor.

Sensitivity assessment. Oyster beds may resist an increase in desiccation at the benchmark level. Both resistance and resilience are assessed as 'High', giving the biotope a 'Not sensitive' assessment at the level of the benchmark.

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

SS.SMx.IMx.Ost is found in sheltered to extremely sheltered conditions. This biotope is found from 0 – 20 m in depth. The shallow wave action in shallow water results in oscillatory water flow, the magnitude of which is greatest in shallow water and attenuated with depth. While the oysters' attachment is permanent, increased wave action may result in erosion of its substratum and the oysters with it. Areas where sufficient shell debris has accumulated may be less vulnerable to this disturbance. However, a proportion of the bed is likely to be displaced by an increase in wave action. Similarly, infaunal species, burrowing polychaetes and epifauna are characteristic of wave sheltered conditions and may be lost, e.g. *Asciidiella* sp. The biotope may be replaced by communities characteristic of stronger wave action and coarser sediments.

Sensitivity assessment. At the benchmark of this pressure it is highly unlikely that the change will cause any effect on this biotope. However an increase above the benchmark of this pressure could have a negative impact. Both the resilience and resistance of this biotope are assessed as 'High', which results in the biotope being classified as 'Not sensitive'.

Chemical Pressures

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

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

In heavily polluted estuaries, e.g. Restronguet Creek in the Fal estuary, oyster flesh was known to turn green due to the accumulation of copper. (Yonge, 1960; Bryan *et al.*, 1987). Bryan *et al.* (1987) noted that in the Cu and Zn were accumulated in the tissues of *Ostrea edulis*, estimates ranging from ca 1000 to ca 16,500 µg/g dry weight, which would probably be toxic for human consumption. *Ostrea edulis* is therefore tolerant of high levels of Cu and Zn and is able to survive in the lower reaches of Restronguet Creek, where other species are excluded by the heavy metal pollution. However, larval stages may be more intolerant, especially to Hg, Cu, Cd and Zn. Bryan (1984) reported at 48 hr LC50 for Hg of 1-3.3 ppb in *Ostrea edulis* larvae compared with a 48 hr LC50 for Hg of 4200 ppb in adults. Although the adult *Ostrea edulis* may be tolerant of heavy metal pollution the larval effects suggest that recruitment may be impaired resulting in a reduction in the population over time, and hence a reduction in the associated fauna.

Little information on the tolerance of ascidians or sponges was found. However, polychaetes are thought to be relatively tolerant of heavy metal pollution, even though some heavy metals may suppress reproduction (Bryan, 1984). Similarly, Bryan (1984) suggested that adult gastropod molluscs were also relatively tolerant of heavy metal pollution. Therefore, most other characteristic species in this biotope may be relatively tolerant of heavy metal pollution.

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.

Polycyclic Aromatic Hydrocarbons (PAH; components of crude oil and derivatives of fossil fuel combustion) are amongst the most water soluble of hydrocarbons, allowing them to be accumulated to high concentrations in the tissues of bivalves. PAHs have been reported to have detrimental effects on the immune system of bivalves including oysters (Woolmer *et al.* 2011 and references therein).

This biotope will probably be partly protected from the direct effects of an oil spill by its subtidal position. However, in sheltered areas oil is likely to persist, and reach the shallow sea bed adsorbed to particulates or in solution. Oil and its fractions has been shown to result in reduced feeding rates in bivalves (e.g. *Crassostrea* sp.) (Bayne *et al.*, 1992; Suchanek, 1993). Oils and their fractions have also been shown to cause genetic abnormalities in *Crassostrea virginica*. Oysters and other bivalves are known to accumulate hydrocarbons in their tissues (Clark, 1997). Polyaromatic hydrocarbons were show to reduce the scope for growth in *Mytilus edulis* and may have a similar effect in other bivalves. Polychaetes, bivalves and amphipods are generally particularly affected by oil spills in infaunal habits, and echinoderms are also particularly intolerant of oil contamination (Suchanek, 1993). Hydrocarbons in the environment probably also affect growth but no information concerning their effects on reproduction were found.

Overall, hydrocarbon contamination would probably affect growth rates of juveniles and adult *Ostrea edulis*, while an oil spill is likely to kill a proportion of the associated community.

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.

The principle source of heavy metals, particularly copper and zinc, present at elevated concentrations in salmon farm sediments, are fish feed and antifoulant paints used on fish cages and associated structures (Wilding & Hughes, 2010 and references therein). Antifoulants are not always used and mechanical cleaning of nets/equipment is often preferred. The use of TBT has not been permitted on aquaculture installations for over 20 years (Marine Institute, 2007).

The effect of pollutants on oysters has been extensively studied. *Crassostrea virginica* was found to be intolerant of halogenated by-products of chlorinated power station cooling waters. Larval growth was adversely affected, and up to 20% larval mortality occurred at 0.05 mg/l (LC50 48 hrs of 1 mg/l. (Cole *et al.*, 1999). Bromoform reduced feeding and gametogenesis at 25 µg/l in *Crassostrea virginica* (Cole *et al.*, 1999). Various detergents, previously used to treat oil spills, were shown to halve the normal development rate of *Ostrea edulis* larvae over the range 2.5 -7.5 ppm,

depending on the type of detergent (Smith, 1968). An increase in development time is likely to increase larval mortality prior to settlement.

Rees *et al.* (2001) suggested that TBT contamination may have locally reduced population sizes of *Ostrea edulis*. In *Ostrea edulis*, TBT has been reported to cause reduced growth of new spat at 20 ng/l, a 50% reduction in growth at 60 ng/l. Although older spat grew normally at 240 ng/l for 7 days, and the prevention of larval production in adults exposed to 240 and 2620 ng/l for 74 days (Thain & Waldock, 1986; Bryan & Gibbs, 1991). Adults bioaccumulate TBT. Thain & Waldock (1986) and Thain *et al.* (1986) noted that TBT retarded normal sex change (male to female) in *Ostrea edulis*.

TBT also has marked effects on other marine organisms. For example TBT causes imposex in prosobranch gastropods, especially the neogastropods such as *Nucella lapillus*, *Ocenebra erinacea* and *Urosalpinx cinerea* resulting in markedly reduced reproductive capacity and population decline. Ascidian larval stages were reported to be intolerant of TBT (Mansueto *et al.*, 1993 cited in Rees *et al.*, 2001). Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* (family Cirratulidae) after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages of these polychaetes. No information concerning the polychaetes characteristic of this biotope were found. Surveys of the Crouch estuary suggested that benthic epifauna were recovering since a reduction in TBT contamination suggesting that populations of several epifaunal species, including *Asciidiella* sp., had previously been reduced (Rees *et al.*, 1999; 2001).

While loss of predatory neogastropods (which are particularly intolerant of TBT) may be of benefit to *Ostrea edulis* populations, TBT has been shown to reduce reproduction and the growth of spat. Rees *et al.* (1999; 2001) reported that the epifauna of the inner Crouch estuary had largely recovered within 5 years (1987-1992) after the ban on the use of TBT on small boats in 1987. Increases in the abundance of *Asciidiella* sp. and *Ciona intestinalis* were especially noted. *Ostrea edulis* numbers increased between 1987 -1992 with a further increase by 1997. However, they noted that the continued increase in *Ostrea edulis* numbers and the continued absence of neogastropods suggested that recovery was still incomplete at the population level.

Radionuclide contamination

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence.

Introduction of other substances

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation

High

Q: High A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: High A: Medium C: Medium

Oysters are considered to be tolerant of periods of hypoxia due to their ability to survive out of

water during transportation for long periods of time, and many weeks at low temperatures (Korringa, 1952; Yonge, 1960). However, the sustained oxygen depletion typical of areas with high organic loading would probably have much more severe effects (Wilding & Hughes, 2010). Although *Ostrea edulis* may be relatively tolerant of low oxygen concentrations other species within the community may be more intolerant (Tyler-Walters, 2008).

Lenihan (1999) reported that *Crassostrea virginica* could withstand hypoxic conditions (< 2mg O² /l) for 7-10 days at 18 °C but last for several weeks at <5 °C. However, Lenihan (1999) also suggested that many days (26) of hypoxia, contributed to the high rate of mortality observed at the base reefs at 6 m depth together with poor condition, parasitism and reduced food availability. In addition, a prolonged period of hypoxia in the River Neuse (North Carolina) resulted in mass mortality of oysters (Lenihan, 1999).

Members of the characterizing species that occur in estuaries e.g. *Asciidiella aspersa* are probably tolerant of a degree of hypoxia and occasional anoxia. Similarly, most polychaetes are capable of a degree of anaerobic respiration (Diaz & Rosenberg, 1995). However, periods of hypoxia and anoxia are likely to result in loss of some members of the infauna and epifauna within this biotope.

Sensitivity assessment. *Ostrea edulis* is not affected by de-oxygenation at the level of the benchmark. However, some of the associated species might be affected at the benchmark level. For this reason the resistance and resilience are assessed as 'High', giving the biotope a 'Not sensitive' sensitivity.

Nutrient enrichment

High

Q: High A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: High A: Medium C: Medium

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The nutrient enrichment of a marine environment leads to organisms no longer being limited by the availability of certain nutrients. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta-analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as a contaminants, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Due to the 'remarkably consistent' affect of marine pollutants on species diversity this finding relevant to this biotope (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls (Johnston & Roberts, 2009).

Moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material, is likely to increase food availability for all the suspension feeders within the biotope. However, long-term or high levels of organic enrichment may result in eutrophication and have indirect adverse effects, such as increased turbidity, increased suspended sediment, increased risk

of deoxygenation and the risk of algal blooms.

Ostrea edulis has been reported to suffer mortality due to toxic algal blooms, e.g. blooms of *Gonyaulax* sp. and *Gymnodinium* sp. (Shumway, 1990). The subsequent death of toxic and non-toxic algal blooms may result in large numbers of dead algal cells collecting on the sea bottom, resulting in local de-oxygenation as the algal decompose, especially in sheltered areas with little water movement where this biotope is found. *Ostrea edulis* may be relatively tolerant of low oxygen concentrations other species within the community may be more intolerant.

Sensitivity assessment. A slight increase in nutrients may enhance food supply to *Ostrea edulis* and increase growth rates in the species. At the pressure benchmark there shouldn't be a negative impact on the biotope. Therefore the resistance and resilience have been assessed as 'High', resulting in an assessment of 'Not Sensitive'.

Organic enrichment

High

Q: High A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: High A: Medium C: Medium

Organic enrichment leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in ecosystem function can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) and decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008). Indirect adverse effects associated with organic enrichment include increased turbidity, increased suspended sediment and the increased risk of deoxygenation.

Nutrient enrichment of the water column is a potential impact arising from finfish aquaculture which can potentially lead to eutrophication and the alteration of the species composition of plankton with possible proliferation of potentially toxic or nuisance species (OSPAR, 2009b). However, the current consensus is that enrichment by salmon farm nutrients is generally too little, relative to natural levels, to have such an effect (SAMS and Napier University 2002, cited in Wilding & Hughes, 2010).

Johnston & Roberts (2009) undertook a review and meta-analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 49 papers reviewed relating to sewage as a contaminant, over 70% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Due to the 'remarkably consistent' effect of marine pollutants on species diversity this finding relevant to this biotope (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls.

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. The lack of direct evidence for *Ostrea edulis* has resulted in this pressure being assessed as 'No evidence'.

A 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

This biotope occurs on sandy mud with some shells and occasionally gravel. If there were a change from this substratum type then the physical conditions required for this biotope would no longer be present. Therefore a change to rock or artificial substrata would cause the biotope to be lost. Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2014) or the presence of non-native species (Bulleri & Airoidi, 2005).

Sensitivity assessment. The biotope has a resistance of 'None', a resilience of 'Very low', and consequently a sensitivity of 'High'.

Physical change (to another sediment type)**Not relevant (NR)**

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Sensitivity assessment. *Ostrea edulis* occur in a range of habitat types and hence are not considered sensitive to an increased sediment coarse fraction. Resistance and resilience are therefore assessed as 'High' resulting in this biotope being considered 'Not sensitive' at the pressure benchmark.

Habitat structure changes - removal of substratum (extraction)**None**

Q: High A: High C: High

Very Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Ostrea edulis cements its lower valve permanently to solid pieces of substratum, such as pebbles, cobbles, boulders etc. The removal of this layer of the substratum would lead to the loss of; the biogenic layer created by oysters and its biological community, the oyster cultch (which will remove an important chemical cue used by larvae when settling), and the substrate which provides a point of attachment for larvae.

Sensitivity assessment. The resistance to the removal of the substratum is 'None'. The resilience of the biotope to this pressure depends on what substratum lies 30 cm below the top layer. If the substratum is the same as that which was removed, resilience is going to be 'Very low'. If the underlying substrate is not suitable for the recovery of this biotope i.e. bedrock, then the biotope will not be able to return at all.

Abrasion/disturbance of the surface of the substratum or seabed

Low

Q: High A: Medium C: Medium

Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Abrasion may cause damage to the shell of *Ostrea edulis*, particularly to the growing edge. Regeneration and repair abilities of the oyster are quite good. Power washing of cultivated oysters routinely causes chips to the edge of the shell increasing the risk of desiccation. This damage is soon repaired by the mantle. Oysters were often harvested by dredging in the past, which their shells survived relatively intact. On mixed sediments, the dredge may remove the underlying sediment, and cobbles and shell material with effects similar to substratum loss above.

In a review of anthropogenic threats to restored *Ostrea edulis* broodstock areas, Woolmer *et al.* (2011) reported that, in general, fishing mortality arising from commercial fisheries (for oysters and other mobile gear fisheries) is a key pressure on native oyster populations and habitats. Impacts include: stock removal, disturbance of spat (juvenile oysters) and habitat disturbances (to oyster banks and reefs). More specifically Woolmer *et al.* (2011) stated that dredging over oyster beds removes both cultch material and target oysters. Over time, with sufficient effort, the net effect is a flattening of the bank and the creation of a flatter bed which is more susceptible to siltation and hypoxia in some water bodies (Woolmer *et al.*, 2011 and references therein). However, they also stated that although dredges have the negative effects stated above, the use of dredges on managed *Ostrea edulis* beds in some areas is often seen as necessary if siltation and smothering by algae and *Crepidula fornicata* are to be controlled.

Polychaetes and other segmented worms were reported to be badly affected by oyster dredging while any bivalves were displaced (Gubbay & Knapman, 1999). In addition, the epifauna associated with horse mussel beds (*Modiolus modiolus*) was found to be particularly sensitive to abrasion due to scallop dredging (see A5.621; Service & Magorrian, 1997). Therefore *Ostrea edulis* and the other characterizing species are probably sensitive to physical disturbance at the benchmark level.

Sensitivity assessment. The characterizing species, *Ostrea edulis*, is somewhat resistant to some abrasion and is able to recover from some damage to shells e.g. chipping caused by pressure washers. However, damage caused to oyster beds and their habitats by commercial fishing is considered to be of importance to levels of mortality and health of oyster beds. Resistance has been assessed as 'Low', the resilience is assessed as 'Low'. This gives the biotope a sensitivity of 'High'.

Penetration or disturbance of the substratum subsurface

Low

Q: Medium A: Medium C: Medium

Low

Q: High A: High C: Medium

High

Q: Medium A: Medium C: Medium

In general, fishing activities that penetrate the substratum to a greater extent (e.g. beam trawls, scallop dredges and demersal trawls) will potentially damage these habitats to a greater degree than fishing activities using lighter gear (e.g. light demersal trawls and seines) (Hall *et al.*, 2008). One of the major reasons for the decline of the oyster population at Chesapeake Bay was mechanical destruction (Rothschild *et al.*, 1994).

Sensitivity assessment. The effect of sub-surface disturbance will be to displace, damage and remove individuals. Shallow disturbance is considered to remove between 25-75% of the

population so that resistance is assessed as 'Low'. Resilience is assessed as 'Low' and sensitivity is therefore considered to be 'High'.

Changes in suspended solids (water clarity)

High

Q: High A: Medium C: Medium

High

Q: High A: High C: Medium

Not sensitive

Q: High A: Medium C: Medium

A decrease in turbidity and hence increased light penetration may result in increased phytoplankton production and hence increased food availability for suspension feeders, including *Ostrea edulis*. Therefore, reduced turbidity may be beneficial. However, increased fouling by red algae may result and compete with juveniles and settling spat for space. In areas of high suspended sediment, a decrease may result in improved condition and recruitment due to a reduction in the clogging of filtration apparatus of suspension feeders and an increase in the relative proportion of organic particulates. However, a decrease in suspended sediments in some areas may reduce food availability resulting in lower growth or reduced energy for reproduction (Tyler-Walters, 2008).

In a field experiment in Canada, the summer growth of *Ostrea edulis*, on coarse sandy substrata, was found to be enhanced at low levels of sediment resuspension and inhibited as sediment deposition increased (Grant *et al.*, 1990, summarised in Ray *et al.*, 2005). In a review of the biological effects of dredging operations, Ray *et al.* (2005) stated that sediment chlorophyll in suspension at low levels may act as a food supplement, enhancing growth, but at higher concentrations may dilute planktonic food resources and suppress food ingestion (Jackson & Wilding, 2009, references therein).

Oysters respond to an increase in suspended sediment by increasing pseudofaeces production with occasional rapid closure of their valves to expel accumulated silt (Yonge, 1960) both of which exert an energetic cost. Korringa (1952) reported that an increase in suspended sediment decreased the filtration rate in oysters. This study is supported by Grant *et al.* (1990) who found declining clearance rates in *Ostrea edulis* in response to an increase in suspended particulate matter. Suspended sediment was also shown to reduce the growth rate of adult *Ostrea edulis* and to result in shell thickening (Moore, 1977). Reduced growth probably results from increased shell deposition and an inability to feed efficiently. Hutchinson & Hawkins (1992) reported that filtration was completely inhibited by 10 mg/l of particulate organic matter and significantly reduced by 5 mg/l. *Ostrea edulis* larvae survived 7 days exposure to up to 4 g/l silt with little mortality. However, their growth was impaired at 0.75 g/l or above (Moore, 1977). Yonge (1960) and Korringa (1952) considered *Ostrea edulis* to be intolerant of turbid (silt laden) environments. Moore (1977) reported that variation in suspended sediment and silted substratum and resultant scour was an important factor restricting oyster spat fall, i.e. recruitment. Therefore, an increase in suspended sediment may have longer term effects of the population by inhibiting recruitment, especially if the increase coincided with the peak settlement period in summer.

The other suspension feeders characteristic of this biotope are probably tolerant of a degree of suspended sediment but an increase, especially of fine silt, would probably interfere with feeding mechanisms, resulting in reduced feeding and a loss of energy through mechanisms to shed or remove silt.

Sensitivity assessment. A short-term increase in sedimentation is unlikely to have an impact on this biotope and its characterizing species. *Ostrea edulis* has a comping mechanism to remove increased levels of silt from within the mantle. This behaviour is energetically expensive, and may cause a decrease in growth rate of the organism, but is unlikely to cause mortality. For these reasons resistance and resilience are assessed as 'High' given a sensitivity score of 'Not sensitive'.

Smothering and siltation rate changes (light)**None**

Q: High A: High C: Medium

Very Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Ostrea edulis is an active suspension feeder on phytoplankton, bacteria, particulate detritus and dissolved organic matter (DOM) (Korringa, 1952; Yonge, 1960). The addition of fine sediment, pseudofaeces or fish food would potentially increase food availability for oysters. But even small increases in sediment deposition have been found to reduce growth rates in *Ostrea edulis* (Grant *et al.*, 1990, cited in Jackson & Wilding, 2009). Smothering by 5 cm of sediment would prevent the flow of water through the oyster that permits respiration, feeding and removal of waste. Wilding & Hughes (2010) stated that *Ostrea edulis* would be unable to survive burial by rapid or continuous deposition of sediment. *Ostrea edulis* is permanently fixed to the substratum and would not be able to burrow up through the deposited material. *Ostrea edulis* can respire anaerobically, and is known to be able to survive for many weeks (Yonge, 1960) or 24 days (Korringa, 1952) out of water at low temperatures used for storage after collection. However, it is likely that at normal environmental temperatures, the population would be killed by smothering. Yonge (1960) reported death of populations of *Ostrea edulis* due to smothering of oyster beds by sediment and debris from the land as a result of flooding (Yonge, 1960). In a review of anthropogenic threats to restored *Ostrea edulis* broodstock areas, Woolmer *et al.* (2011) reported that the deposition of faeces and waste food from finfish aquaculture developments or deposition from shellfish culture developments (particularly mussel bottom culture) may present a smothering risk to *Ostrea edulis* beds directly below or close by.

Oyster larvae require clean hard surfaces on which to settle (Laing *et al.*, 2005; UMBS, 2007 both cited in Woolmer *et al.*, 2011). A layer of settled material of 1-2 mm in depth was reported to prevent satisfactory oyster sets, i.e. settlement, reducing effective recruitment (Galtsoff, 1964 – *Crassostrea virginica*, Wilbur, 1971, cited in Jackson & Wilding, 2009).

Smothering will probably also kill the sessile, fixed members of the epifauna, unless large enough to protrude above the deposited layer (e.g. *Ascidella* sp.). However, burrowing infauna will probably burrow to the surface. Death of the oyster bed will exacerbate changes in the sediment surface and nutrient levels in the long-term, so that the characterizing species may be replaced by others such as the non-native species *Crepidula fornicata*.

Sensitivity assessment. *Ostrea edulis* would be unable to survive this pressure at the benchmark. As filter feeders that are permanently attached to the substrate they would be unable to borrow up to the surface to enable basic life functions to occur. The low tidal streams within this biotope, in addition to the extremely sheltered to sheltered wave exposure mean that there would be low levels of sediment resuspension. Resulting in the sediment remaining within the biotope for a longer period of time, consolidating the negative effect of the pressure. Resistance to the pressure is 'None', resilience is 'Very low' and the biotope sensitivity at this pressure benchmark is given as 'High'.

Smothering and siltation rate changes (heavy)**None**

Q: High A: High C: Medium

Very Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

No direct evidence was found to assess this pressure at the benchmark. A deposit at the pressure benchmark would cover all species with a thick layer of fine materials. Species associated with this biotope would not be able to escape and would likely suffer mortality (see evidence for light siltation). *Ostrea edulis* would be unable to survive this pressure at the benchmark. As filter

feeders that are permanently attached to the substratum they would be unable to borrow up to the surface to enable basic life functions to occur. The low tidal streams within this biotope, in addition to the extremely sheltered to sheltered wave exposure mean that there would be low levels of sediment resuspension. This could possibly exacerbate the negative impacts of this pressure. The same assessment has been used for this pressure as in the light pressure benchmark. Resistance to the pressure is 'None', resilience is 'Very low' and sensitivity is given as 'High'.

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
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Not assessed.

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

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR
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Species characterizing this habitat do not have hearing perception but vibrations may cause an impact, however no studies exist to support an assessment.

Introduction of light or shading	High Q: Medium A: Medium C: Medium	High Q: High A: High C: Medium	Not sensitive Q: Medium A: Medium C: Medium
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The native oyster has no dependence on light availability, so changes in turbidity and thus light reaching the seabed, for example, would have no direct effect on this feature. However, prevention of light reaching the seabed may affect *Ostrea edulis* indirectly through changes in phytoplankton abundance and primary production. Red algae found in the biotope *Ostrea edulis* beds on shallow sublittoral muddy mixed sediments will be affected by a reduction in primary production. Red algae are probably shade tolerant but may be lost from deeper examples of this biotope (Tyler-Walters, 2008).

Sensitivity assessment. Resistance and resilience are assessed as 'High', resulting in an assessment of 'Not sensitive'.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR
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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 propagule dispersal. But propagule dispersal is not considered under the pressure definition and benchmark.

Death or injury by collision

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant to seabed habitats.

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

Visual disturbance

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant.

 Biological Pressures

Resistance

Resilience

Sensitivity

Genetic modification & translocation of indigenous species

None

Q: High A: Medium C: Medium

Very Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Organisms are frequently transplanted from one location to another in marine aquaculture and these transplanted species may pose potentially serious impacts to native populations through interbreeding and thus alteration of the gene pool.

The Pacific oyster (*Magallana gigas*) have been intentionally imported from Japan into Ireland because they are larger and faster growing than the native oyster (*Ostrea edulis*). Pacific oysters cannot hybridize with the native oyster but indirect effects may occur through alterations in gene frequencies as a result of ecological interactions with the Pacific oyster (Heffernan 1999).

Sensitivity assessment. Very little information is available on the effect of this pressure on the characterizing species *Ostrea edulis*. *Ostrea edulis* may be translocated, resistance to genetic impacts is assessed as 'None' and recovery as 'Low' due to potential for permanent effects. Sensitivity is therefore categorised as 'High'.

Introduction or spread of invasive non-indigenous species

Low

Q: Medium A: Medium C: Medium

Very Low

Q: High A: High C: Medium

High

Q: Medium A: Medium C: Medium

Kohler & Courtenay (1986) summarised the effects of invasive non-indigenous species (INIS) in marine environments. The effects included habitat, trophic and spatial alteration, gene pool deterioration and the introduction of disease (Kohler & Courtenay, 1986). The slipper limpet *Crepidula fornicata* has a high potential to cause damage within this biotope. This species was introduced with American oyster between 1887 - 1890 and has become a serious pest on oyster beds. *Crepidula fornicata* competes for space with oyster, and the build-up of its faeces and pseudofaeces smothers oysters and renders the substratum unsuitable for settlement (Blanchard, 1997; Eno *et al.*, 1997, 2000). Where abundant, *Crepidula fornicata* may prevent recolonization by *Ostrea edulis* and may change the entire biotope, to produce a *Crepidula fornicata* dominated biotope such as SS.SMx.SMxVS.CreMed (Connor *et al.*, 2004).

The American oyster drill *Urosalpinx cinerea* was first recorded in 1927 and occurs in south east and south west of the UK. *Urosalpinx cinerea* is a major predator of oyster spat and was considered to be a major pest on native and cultured oyster beds (Korringa, 1952; Yonge, 1960) and contributed to the decline in oyster populations in the first half of the 20th century.

Didemnum vexillum (leathery sea squirt) was first recorded in the UK in Holyhead marina in 2008 (Laing *et al.*, 2011). This species can colonize a range of substrata, including that which is characteristic of this biotope. There are very few studies of the effects of *Didemnum vexillum* on biotopes, and there are none considering this biotope. However, it is likely that a biotope smothered by this species would experience a reduction in biodiversity and potentially a change in the biotope (Laing *et al.*, 2011).

The American oyster drill *Urosalpinx cinerea* was first recorded in 1927 and occurs in south east and south west of the UK. *Urosalpinx cinerea* is a major predator of oyster spat and was considered to be a major pest on native and cultured oyster beds (Korringa, 1952; Yonge, 1960) and contributed to the decline in oyster populations in the first half of the 20th century.

Sensitivity assessment. Several INIS could potentially impact oyster beds. In particular, *Crepidula* is reported to damage oyster culture, and is thought to prevent oyster bed recovery and compete for habitat, while oyster drills affect oyster culture and native oyster beds. Therefore, resistance is assessed as 'Low'. A resilience of 'Very low' has been recorded since the successful removal of an INIS is extremely rare, which will mean that the biotope is likely to change. Hence, sensitivity is assessed as 'High'. Due to the constant risk of new invasive species, the literature for this pressure should be revisited.

Introduction of microbial pathogens

Low

Q: High A: Medium C: Medium

Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Numerous diseases and parasites have been identified in oysters, partly due to their commercial importance and partly because of incidences of disease related mass mortalities in oyster beds. Diseases in oysters and other commercial bivalve species may be caused by bacteria (especially in larvae), protists, fungi, coccidians, gregarines, trematodes, while annelids and copepods may be parasite. The reader should refer to reviews by Lauckner (1983) and Bower & McGladdery (1996) for further detail. The following species have caused mortalities in *Ostrea edulis* populations in the UK.

Polydora ciliata burrows into the shell, weakening the shell and increasing the oysters vulnerability to predation and physical damage, whereas *Polydora hoplura* causes shell blisters. Boring sponges of the genus *Cliona* may bore the shell of oysters caused shell weakening, especially in older specimens. The flagellate protozoan *Heximata* sp. resulted in mass mortalities on natural and cultivated beds of oysters in Europe in the 1920-21, from which many population did not recover (Yonge, 1960). The parasitic protozoan *Bonamia ostreae* caused mass mortalities in France, the Netherlands, Spain, Iceland and England after its accidental introduction in 1980's resulting a further reduction in oyster production (Edwards, 1997). Another protozoan parasite *Marteilia refringens*, present in France has not yet affected stocks in the British Isles, and the copepod parasite, *Mytilicola intestinalis*, of mussels, has also been found to infect *Ostrea edulis* potentially causing considerable loss of condition, although in most infections there is no evidence of pathology.

The transportation of Pacific oysters from Japan to the west coast of North America is thought to

have resulted in the introduction of the bacterium *Nocardia crassostreae* leading to nocardiosis (bacterial infection that can invade every tissue) in Pacific oysters (*Magallana gigas*) and *Ostrea edulis* (Forrest *et al.*, 2009; taken from Tillin *et al.*, 2013).

The protistan parasite *Bonamia ostrea* is a serious threat to *Ostrea edulis* in the UK (Laing *et al.*, 2005, cited in Woolmer *et al.* 2011). *Bonamia ostrea* has caused mortality of *Ostrea edulis* throughout northern Europe, with disease events reducing populations by 80% or higher Heffernan (1999). Disease transmission can occur from oyster to oyster. However, *Bonamia ostrea* is also found in other marine invertebrates, including zooplankton (indicating the possibility of interspecies transmission; Lynch *et al.*, 2007 cited in Woolmer *et al.*, 2011). *Ostrea edulis* larvae may also be vectors for disease between populations; Arzul *et al.*, 2011 cited in Woolmer *et al.*, 2011).

Sensitivity assessment. Although the impact of individual species of microbial pathogen on *Ostrea edulis* varies, pathogens known to affect this species in the UK can cause significant mortality. *Bonamia ostrea* is known to cause in excess of 80 % mortality of oyster beds within the UK. For this reason both the resistance and resilience have been assessed as 'Low'. Giving the biotope a sensitivity of 'High'.

Removal of target species

None

Q: High A: Medium C: Medium

Low

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Ostrea edulis is long lived, has notably unreliable reproduction, and low levels of recruitment, which makes it vulnerable to over fishing (Orton, 1927; Spärck, 1951; Laing *et al.*, 1951; taken from Gravestock *et al.*, 2014). British native oyster beds were exploited in Roman times. The introduction of oyster dredging in the mid 19th century developed the oyster beds into one of Britain's largest fisheries, employing about 120,000 men around the coast in the 1880's. However, by the late 19th century stocks were beginning to be depleted so that by the 1950s the native oyster beds were regarded as scarce (Korringa, 1952; Yonge, 1960; Edwards, 1997). This biotope is still regarded as scarce today. Over-fishing, combined with reductions in water quality, cold winters (hence poor spat fall), flooding, the introduction of non-native competitors and pests, outbreaks of disease and severe winters were blamed for the decline (Korringa, 1952; Yonge, 1960; Edwards, 1997). As a result, although 700 million oysters were consumed in London alone in 1864, the catch fell from 40 million in 1920 to 3 million in the 1960s; from which the catch has not recovered (Edwards, 1997). Most populations are now artificially laid for culture and protected by Protection Orders (Fowler, 1999; Edwards, 1997).

The *Ostrea edulis* fishery in The Solent was once considered to be the largest self-sustaining fishery in Europe (Gravestock *et al.*, 2014). However, since the turn of the 20th century the population has collapsed significantly three times. The first collapse occurred between 1919 – 1921 due to a disease epidemic caused by the flagellate protozoan *Hexamita* (Tubbs, 1999). The second collapse was caused by the 1962 - 1963 winter, during which temperatures were significantly below average (Kamphausen, 2012). And finally in 2006 when poor recruitment led to sharp drop in the population (Gravestock *et al.*, 2014). Although a number of potential causes of recruitment failure have been suggested (see Gravestock *et al.*, 2014), it is suggested that overfishing exacerbated the effect of poor recruitment.

Sensitivity assessment. The current rarity of oyster beds in the UK is due to the pressure the populations were put under due to commercial fishing. Stock from beds can remain sustainable under commercial fishing pressure. However, if these populations have a period of bad

recruitment or are being affected by another negative pressure, then fishing can compound this effect. *Ostrea edulis* have no ability to remove themselves from fishing pressure as they are preminantly attached to the substrate once they have settled from larvae. For this reason resilience of this biotope is given as 'None'. A number of native oyster beds in the UK have been destroyed by fishing and have had to undergo human intervention to return the oyster population. In some areas oysters have not returned. Resilience is assessed as 'Very low', resulting in a 'High' sensitivity score.

Removal of non-target species

Low

Q: Medium A: Medium C: Medium

Medium

Q: High A: High C: Medium

Medium

Q: Medium A: Medium C: Medium

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. *Ostrea edulis* is the dominant species within this biotope so they could easily be incidentally removed from this biotope as by-catch when other species are being targeted. The loss of these species and other associated species would decrease species richness and negatively impact on the ecosystem function.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope. The resistance to removal is 'Low' due to the easy accessibility of the biotopes location and the inability of these species to evade collection. Resilience is 'Medium', with recovery only being able to begin when the harvesting pressure is removed altogether. Therefore, gives an overall sensitivity score of 'Medium' is recorded.

Bibliography

- Anonymous, 1999b. Native oyster (*Ostrea edulis*). Species Action Plan. In *UK Biodiversity Group. Tranche 2 Action Plans. English Nature for the UK Biodiversity Group, Peterborough., English Nature for the UK Biodiversity Group, Peterborough.*
- Arzul, I., Langlade, A., Chollet, B., Robert, M., Ferrand, S., Omnes, E., Lerond, S., Couraleau, Y., Joly, J.P., François, C. & Garcia, C., 2011. Can the protozoan parasite *Bonamia ostreae* infect larvae of flat oysters *Ostrea edulis*? *Veterinary Parasitology*, **179**, 69-76.
- Bayne, B., 1969. The gregarious behaviour of the larvae of *Ostrea edulis* L. at settlement. *Journal of the Marine Biological Association of the United Kingdom*, **49**(2), 327-356.
- Bayne, B.L., Widdows, J., Moore, M.N., Salkeld, P., Worrall, C.M. & Donkin, P., 1982. Some ecological consequences of the physiological and biochemical effects of petroleum compounds on marine molluscs. *Philosophical Transactions of the Royal Society of London B*, **297**, 219-239.
- Beaumont, A.R., Newman, P.B., Mills, D.K., Waldock, M.J., Miller, D. & Waite, M.E., 1989. Sandy-substrate microcosm studies on tributyl tin (TBT) toxicity to marine organisms. *Scientia Marina*, **53**, 737-743.
- Bergman, M.J.N. & Van Santbrink, J.W., 2000b. Fishing mortality of populations of megafauna in sandy sediments. In *The effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & S.J. de Groot), 49-68. Oxford: Blackwell Science.
- Blanchard, M., 1997. Spread of the slipper limpet *Crepidula fornicata* (L.1758) in Europe. Current state and consequences. *Scientia Marina*, **61**, Supplement 9, 109-118.
- Bower, S.M. & McGladdery, S.E., 1996. Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish. SeaLane Diseases of Shellfish. [on-line]. <http://www-sci.pac.dfo-mpo.gc.ca/sealane/aquac/pages/toc.htm>, 2000-11-27
- Bricker, S.B., Clement, C.G., Pirhalla, D.E., Orlando, S.P. & Farrow, D.R., 1999. National estuarine eutrophication assessment: effects of nutrient enrichment in the nation's estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, MD, 71 pp.
- Bricker, S.B., Longstaff, B., Dennison, W., Jones, A., Boicourt, K., Wicks, C. & Woerner, J., 2008. Effects of nutrient enrichment in the nation's estuaries: a decade of change. *Harmful Algae*, **8** (1), 21-32.
- Bryan, G.W. & Gibbs, P.E., 1991. Impact of low concentrations of tributyltin (TBT) on marine organisms: a review. In: *Metal ecotoxicology: concepts and applications* (ed. M.C. Newman & A.W. McIntosh), pp. 323-361. Boston: Lewis Publishers Inc.
- Bryan, G.W., 1984. Pollution due to heavy metals and their compounds. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters*, vol. 5. *Ocean Management*, part 3, (ed. O. Kinne), pp.1289-1431. New York: John Wiley & Sons.
- Bryan, G.W., Gibbs, P.E., Hummerstone, L.G. & Burt, G.R., 1987. Copper, Zinc, and organotin as long-term factors governing the distribution of organisms in the Fal estuary in southwest England. *Estuaries*, **10**, 208-219.
- Bulleri, F. & Airoidi, L., 2005. Artificial marine structures facilitate the spread of a non-indigenous green alga, *Codium fragile* ssp. *tomentosoides*, in the north Adriatic Sea. *Journal of Applied Ecology*, **42** (6), 1063-1072.
- Buxton, C.D., Newell, R.C. & Field, J.G., 1981. Response-surface analysis of the combined effects of exposure and acclimation temperatures on filtration, oxygen consumption and scope for growth in the oyster *Ostrea edulis*. *Marine Ecology Progress Series*, **6**, 73-82.
- Clark, R.B., 1997. *Marine Pollution*, 4th ed. Oxford: Carendon Press.
- Cole, H. & Knight-Jones, E.W., 1939. Some observations and experiments on the setting behaviour of larvae of *Ostrea edulis*. *Journal du Conseil Permanent International pour L'Exploration de la Mer*, **14**, 86-105.
- Cole, H. & Knight-Jones, E.W., 1949. The setting behaviour of larvae of the European flat oyster, *O. edulis* L. and its influence on methods of cultivation and spat collection. *Ministry of Agriculture, Fisheries and Food, Fisheries Investigations Series II*, **17**, 1-39.
- Cole, H.A., 1951. The British oyster industry and its problems. *Rapports and Proces-Verbaux des Reunions. Conseil Permanent International pour l'Exploration de la Mer*, **128**, 7-17.
- 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., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03*. [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from <https://mhc.jncc.gov.uk/>
- Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. & Sanderson, W.G., 1997a. Marine biotope classification for Britain and Ireland. Vol. 2. Sublittoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report no. 230, Version 97.06., Joint Nature Conservation Committee, Peterborough, JNCC Report no. 230, Version 97.06.*
- Dame, R.F., 1992. The role of bivalve filter feeder material fluxes in estuarine ecosystems. In *Bivalve filter feeders in estuarine and coastal ecosystem processes* (ed. R.F. Dame), pp. 246-269. Berlin: Springer-Verlag. [NATO Advanced Science Institute Series G: Ecological Sciences, vol. 33.]
- Dame, R.F.D., 1996. *Ecology of Marine Bivalves: an Ecosystem Approach*. New York: CRC Press Inc. [Marine Science Series.]

- 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.
- Davis, H.C. & Calabrese, A., 1969. Survival and growth of larvae of the European oyster (*Ostrea edulis* L.) at different temperatures. *Biological Bulletin, Marine Biological Laboratory, Woods Hole*, **136**, 193-199.
- DEP 2007. *Water quality improvement plan for the Derwent estuary*. Derwent Estuary Program & Australian Government Coastal Catchments Initiative & State Government. Tasmania.
- Diaz, R.J. & Rosenberg, R., 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: an Annual Review*, **33**, 245-303.
- Edwards, E., 1997. Molluscan fisheries in Britain. In *The History, Present Condition, and Future of the Molluscan Fisheries of North and Central American and Europe*, vol. 3, *Europe*, (ed. C.L. MacKenzie, Jr., V.G. Burrell, Jr., Rosenfield, A. & W.L. Hobart). *National Oceanic and Atmospheric Administration*, NOAA Technical Report NMFS 129.
- Eno, N.C., Clark, R.A. & Sanderson, W.G. (ed.) 1997. *Non-native marine species in British waters: a review and directory*. Peterborough: Joint Nature Conservation Committee.
- Firth, L., Thompson, R., Bohn, K., Abbiati, M., Airoidi, L., Bouma, T., Bozzeda, F., Ceccherelli, V., Colangelo, M. & Evans, A., 2014. Between a rock and a hard place: Environmental and engineering considerations when designing coastal defence structures. *Coastal Engineering*, **87**, 122-135.
- Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore*. Cambridge: Cambridge University Press.
- Fitt, W.K., Coon, S.L., Walch, M., Weiner, R.M., Colwell, R.R. & Gonar, D.B., 1990. Settlement behaviour and metamorphosis of oyster larvae (*Crassostrea gigas*) in response to bacterial supernatants. *Marine Biology*, **106**, 389-394.
- Fowler, S.L., 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. *Natura 2000 report prepared by the Nature Conservation Bureau Ltd. for the UK Marine SACs Project*, 132 pp., Peterborough: English Nature (UK Marine SACs Project), <http://www.english-nature.org.uk/uk-marine/reports/reports.htm>
- Galtsoff, P., 1964. The American Oyster *Crassostrea virginica* Gmelin. *Fishery Bulletin of the Fish and Wildlife Service*, **64**, 1-480
- Grant, J., Enright, C.T. & Griswold, A., 1990. Resuspension and growth of *Ostrea edulis*: a field experiment. *Maine Biology*, **104**, 51-59.
- Gravestock, V., James, F. & Goulden, M., 2014. Solent native oyster (*Ostrea edulis*) restoration - Literature Review & Feasibility Study. *MacAlister Elliot & Partners, On behalf of the Blue Marine Foundation, Report*, no. 2897.
- Green, D., Chapman, M. & Blockley, D., 2012. Ecological consequences of the type of rock used in the construction of artificial boulder-fields. *Ecological Engineering*, **46**, 1-10.
- Gubbay, S., & Knapman, P.A., 1999. *A review of the effects of fishing within UK European marine sites*. Peterborough, English Nature.
- Hall, K., Paramour, O.A.L., Robinson, L.A., Winrow-Giffin, A., Frid, C.L.J., Eno, N.C., Dernie, K.M., Sharp, R.A.M., Wyn, G.C. & Ramsay, K., 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters - development of a protocol. *CCW (Policy Research) Report No: 8/12, Countryside Council for Wales (CCW), Bangor*, 85 pp.
- Hancock, D.A., 1954. The destruction of oyster spat by *Urosalpinx cinerea* (Say) on Essex oyster beds. *Journal du Conseil*, **20**, 186-196.
- Hancock, D.A., 1955. The feeding behaviour of starfish on Essex oyster beds. *Journal of the Marine Biological Association of the United Kingdom*, **34**, 313-337.
- Hancock, D.A., 1958. Notes on starfish on an Essex oyster bed. *Journal of the Marine Biological Association of the United Kingdom*, **37**, 565-589.
- Hawkins, L.E., Hutchinson, S. & Askew, C., 2005. Evaluation of some factors affecting native oyster stock regeneration. *Shellfish News*, **19**, 10-12.
- Heffernan, M., 1999. A review of the ecological implications of mariculture and intertidal harvesting in Ireland: *Dúchas*.
- Howson, C.M., Connor, D.W. & Holt, R.H.F., 1994. The Scottish sealochs - an account of surveys undertaken for the Marine Nature Conservation Review. *Joint Nature Conservation Committee Report*, No. 164 (Marine Nature Conservation Review Report MNCR/SR/27), Joint Nature Conservation Committee Report, No. 164 (Marine Nature Conservation Review Report MNCR/SR/27).
- Hutchinson, S. & Hawkins, L.E., 1992. Quantification of the physiological responses of the European flat oyster, *Ostrea edulis* L. to temperature and salinity. *Journal of Molluscan Studies*, **58**, 215-226.
- Jackson, A. & Wilding, C., 2009. *Ostrea edulis*. Native oyster. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [On line]. Plymouth: Marine Biological Association of the United Kingdom. [cites 03.02.16]. Available from: <http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3997>
- 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>
- Johnston, E.L. & Roberts, D.A., 2009. Contaminants reduce the richness and evenness of marine communities: a review and meta-

- analysis. *Environmental Pollution*, **157** (6), 1745-1752.
- Kamphausen, L.M., 2012. *The reproductive processes of a wild population of the European flat oyster Ostrea edulis in the Solent*. UK. Ph.D. thesis. University of Southampton. UK. 153 pp.
- Kennedy, R.J. & Roberts, D., 1999. A survey of the current status of the flat oyster *Ostrea edulis* in Strangford Lough, Northern Ireland, with a view to the restoration of its Oyster Beds.. *Biology and Environment: Proceedings of The Royal Irish Academy*. **99B**, 79–88.
- Kinne, O. (ed.), 1970. *Marine Ecology: A Comprehensive Treatise on Life in Oceans and Coastal Waters. Vol. 1 Environmental Factors Part 1*. Chichester: John Wiley & Sons
- Kohler, C.C. & Courtenay Jr, W.R., 1986b. Regulating introduced aquatic species: a review of past initiatives. *Fisheries*, **11** (2), 34-38.
- Kohler C.C. & Courtenay, W.R., 1986a. American Fisheries Society position on introductions of aquatic species. *Fisheries*, **11** (2), 39-42.
- Korringa, P., 1951. The shell of *Ostrea edulis* as a habitat. *Archives Néerlandaises de Zoologie*, **10**, 33-152.
- Korringa, P., 1952. Recent advances in oyster biology. *Quarterly Review of Biology*, **27**, 266-308 & 339-365.
- Laing, I., Bussell, J. & Somerwill, K., 2010. Project report: Assessment of the impacts of *Didemnum vexillum* and options for the management of the species in England. CEFAS. 62 pp.
- Laing, I., Walker, P. & Areal, F., 2005. 2005. A feasibility study of native oyster (*Ostrea edulis*) stock regeneration in the United Kingdom. CEFAS.
- Lancaster, J. (ed), McCallum, S., A.C., L., Taylor, E., A., C. & Pomfret, J., 2014. Development of Detailed Ecological Guidance to Support the Application of the Scottish MPA Selection Guidelines in Scotland's seas. *Scottish Natural Heritage Commissioned Report No.491 (29245)*, Scottish Natural Heritage, Inverness, 40 pp.
- Lauckner, G., 1983. Diseases of Mollusca: Bivalvia. In *Diseases of marine animals. Vol. II. Introduction, Bivalvia to Scaphopoda* (ed. O. Kinne), pp. 477-961. Hamburg: Biologische Anstalt Helgoland.
- Lenihan, H.S., 1999. Physical-biological coupling on oyster reefs: how habitat structure influences individual performance. *Ecological Monographs*, **69**, 251-275.
- Lynch, S.A., Armitage, D.V., Coughlan, J., Mulcahy, M.F. & Culloty, S.C., 2007. Investigating the possible role of benthic macroinvertebrates and zooplankton in the life cycle of the haplosporidian *Bonamia ostreae*. *Experimental Parasitology*, **115** (4), 359-368.
- Macleod C.K. & Eriksen, R.S., 2009. *A review of the ecological impacts of selected antibiotics and antifoulants currently used in the Tasmanian salmonid farming industry (Marine Farming Phase)*. Fisheries Research and Development Corporation and University of Tasmania, Project, no. 2007/246.
- Mansueto, C., Gianguzza, M., Dolcemasclo, G. & Pellerito, L., 1993. Effects of Tributyltin (IV) chloride exposure on early embryonic stages of *Ciona intestinalis*: in vivo and ultrastructural investigations. *Applied Organometallic Chemistry*, **7**, 391-399.
- Marine Institute, 2007. *Veterinary treatments and other substances used in finfish aquaculture in Ireland*. Report prepared by the Marine Institute for SWRBD, March 2007.
- Mesías-Gansbiller, C., Silva, A., Maneiro, V., Pazos, A., Sánchez, J.L. & Pérez-Parallé, M.L., 2013. Effects of chemical cues on larval settlement of the flat oyster (*Ostrea edulis* L.): A hatchery approach. *Aquaculture*, **376**, 85-89.
- Millar, R.H., 1961. Scottish oyster investigations 1948-1958. *Marine Research series, Department of Agriculture and Fisheries for Scotland*, no. 3.
- Millar, R.H., 1963. Investigations of the oyster beds in Loch Ryan. *Marine Research series, Department of Agriculture and Fisheries for Scotland*, no. 5.
- Mistakidis, M.N., 1951. Quantitative studies of the bottom fauna of Essex oyster grounds. *Fishery Investigations, Series 2*, **17**, 47pp.
- Moore, P.G., 1977a. Inorganic particulate suspensions in the sea and their effects on marine animals. *Oceanography and Marine Biology: An Annual Review*, **15**, 225-363.
- Orton J.H., 1927. Observation and Experiments on Sex-Change in the European Oyster (*O. edulis*): Part I. The Change from Female to Male. *Journal of the Marine Biological Association of the United Kingdom (New Series)*, **14** (4), 967-1045.
- Orton, J.H., 1940. Effect of the severe frost of the winter of 1939-40 on the fauna of the Essex oyster beds. *Nature*, **145**, 708-709.
- Peterson, C.H., Summerson, H.C., Thomson, E., Lenihan, H.S., Grabowski, J., Manning, L., Micheli, F. & Johnson, G., 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. *Bulletin of Marine Science*, **66**, 759-774.
- Philpots, J.R., 1890. *Oysters and all about them*. (2 volumes). London: John Richardson & Co.
- 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*.
- Purchon, R.D., 1977. *The biology of the mollusca*, 2nd ed. Oxford: Pergamon Press.
- Ray, G.L., 2005. *Invasive marine and estuarine animals of the Pacific northwest and Alaska*. DTIC Document.
- Rees, H.L., Waldock, R., Matthiessen, P. & Pendle, M.A., 1999. Surveys of the epibenthos of the Crouch Estuary (UK) in relation to

- TBT contamination. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 209-223.
- Rees, H.L., Waldoock, R., Matthiessen, P. & Pendle, M.A., 2001. Improvements in the epifauna of the Crouch estuary (United Kingdom) following a decline in TBT concentrations. *Marine Pollution Bulletin*, **42**, 137-144.
- Roberts, C., Smith, C., H., T. & Tyler-Walters, H., 2010. Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. *Report to the Environment Agency from the Marine Life Information Network and ABP Marine Environmental Research Ltd*. Environment Agency Evidence Report: SC080016/R3., Environment Agency, Peterborough, pp. <http://publications.environment-agency.gov.uk/PDF/SCHO1110BTEQ-E-E.pdf>
- Rothschild, B., Ault, J., Gouilletquer, P. & Heral, M., 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. *Marine Ecology Progress Series*, **111** (1-2), 29-39.
- Service, M. & Magorrian, B.H., 1997. The extent and temporal variation of disturbance to epibenthic communities in Strangford Lough, Northern Ireland. *Journal of the Marine Biological Association of the United Kingdom*, **77**, 1151-1164.
- Sewell, J. & Hiscock, K., 2005. Effects of fishing within UK European Marine Sites: guidance for nature conservation agencies. *Report to the Countryside Council for Wales, English Nature and Scottish Natural Heritage from the Marine Biological Association*. Plymouth, Marine Biological Association. [CCW Contract FC 73-03-214A].
- Shumway, S.E., 1990. A review of the effects of algal blooms on shellfish and aquaculture. *Journal of the World Aquaculture Society*, **21**, 65-104.
- Smith, J.E. (ed.), 1968. 'Torrey Canyon'. *Pollution and marine life*. Cambridge: Cambridge University Press.
- Spärck, R., 1951. Fluctuations in the stock of oyster (*Ostrea edulis*) in the Limfjord in recent time. *Rapports et Procès-verbaux des Réunions. Conseil Permanent International pour L'exploration de la Mer*, **128**, 27-29.
- Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.
- Thain, J.E. & Waldoock, M.J., 1986. The impact of tributyl tin (TBT) antifouling paints on molluscan fisheries. *Water Science and Technology*, **18**, 193-202.
- Thain, J.E., Waldoock, M.J. & Helm, M., 1986. The effect of tri-butyl-tin on the reproduction of the oyster, *Ostrea edulis*. *ICES Council Meeting Paper*, CM 1986/E:14.
- Tillin, H.M. & Hull, S.C., (2013) Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 sites. Report VI: Biogenic Reefs (Sabellaria, Native Oyster, Maerl). *Report No. R.2068. Report by ABPmer for the Marine Institute (Galway)*.
- Tillin, H.M. & Hull, S.C., 2013g. Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 sites. Report VII: Intertidal and Subtidal Reefs. *Report No. R.2074. Report by ABPmer for the Marine Institute (Galway)*.
- Tillin, H.M., Hull, S.C. & Tyler-Walters, H., 2010. Development of a sensitivity matrix (pressures-MCZ/MPA features). *Report to the Department of the Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK.*, Defra Contract no. MB0102 Task 3A, Report no. 22., London, 145 pp.
- Tritar, S., Prieur, D. & Weiner, R., 1992. Effects of bacterial films on the settlement of the oysters, *Crassostrea gigas* (Thunberg, 1793) and *Ostrea edulis* (Linnaeus, 1750) and the scallop *Pecten maximus* (Linnaeus, 1758). *Journal of Shellfish Research*, **11** (2), 325-330.
- Tubbs, C., 1999. *The Ecology, Conservation and History of the Solent*. Chichester: Packard Publishing Ltd, 179pp.
- Tyler-Walters, H., 2008. *Echinus esculentus*. Edible sea urchin. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. [cited 26/01/16]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk/species/detail/1311>
- UKTAG, 2014. UK Technical Advisory Group on the Water Framework Directive [online]. Available from: <http://www.wfduk.org>
- UMBS 2007. Conservation of the native oyster *Ostrea edulis* in Scotland. Scottish Natural Heritage Commissioned Report, No. 251 (ROAME No. F02AA408). 186 pp.
- Valero, J., 2006. *Ostrea edulis* Growth and mortality depending on hydrodynamic parameters and food availability. *Department of Marine Ecology, Gøteborg University, Strömstad, Sweden*. pp. 47.,
- Walne P., 1974. *Culture of Bivalve Molluscs: 50 years' experience at Conwy*. Fishing News Books Ltd (No. Ed. 2), Oxford.
- Walne, P., 1964. Observations on the fertility of the oyster (*Ostrea edulis*). *Journal of the Marine Biological Association of the United Kingdom*, **44** (02), 293-310.
- Waugh, G.D., 1964. Effect of severe winter of 1962-63 on oysters and the associated fauna of oyster grounds of southern England. *Journal of Animal Ecology*, **33**, 173-175.
- Widdows, J., 1991. Physiological ecology of mussel larvae. *Aquaculture*, **94**, 147-163.
- Wilbur, C.G., 1971. Turbidity. Animals. In *Marine Ecology. A comprehensive integrated treatise on life in oceans and coastal waters*, vol. 1, part 2 (Ed. O. Kinne), pp. 1181-1189. London: Wiley-Interscience.
- Wilding T. & Hughes D., 2010. A review and assessment of the effects of marine fish farm discharges on Biodiversity Action Plan habitats. *Scottish Association for Marine Science, Scottish Aquaculture Research Forum (SARF)*.
- Woolmer, A.P., Syvret, M. & Fitzgerald, A., 2011. Restoration of Native Oyster, *Ostrea edulis*, in South Wales: Options and Approaches. *CCW Contract Science Report*, no: 960, pp. 93.
- Yonge, C.M., 1960. *Oysters*. London: Collins.