MarLIN

Marine Information Network

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

Native oyster (*Ostrea edulis*)

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

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

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/species/detail/1146]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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A view of the upper (right) side of a native oyster attached to pebbles.
Photographer: Keith Hiscock
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See online review for distribution map

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

Researched by	Frances Perry & Angus Jackson	**Refereed by**	This information is not refereed.
Authority	Linnaeus, 1758		
Other common names	Flat oyster, European oyster	**Synonyms**	-

Summary

Description

The native oyster *Ostrea edulis* has an oval or pear-shaped shell with a rough, scaly surface. The two halves (valves) of the shell are different shapes. The left valve is concave and fixed to the substratum, the right being flat and sitting inside the left. The shell is off-white, yellowish or cream in colour with light brown or bluish concentric bands on the right valve. *Ostrea edulis* grows up to 11 cm long, rarely larger. The inner surfaces are pearly, white or bluish-grey, often with darker blue areas.

Recorded distribution in Britain and Ireland

Widely distributed around the British Isles but less so on the east and north-east coasts of Britain and Ireland. The main stocks are now in the west coast of Scotland, the south-east and Thames estuary, the Solent, the River Fal, and Lough Foyle.

Global distribution

Found naturally from the Norwegian Sea south through the North Sea down to the Iberian Peninsula and the Atlantic coast of Morocco. Found in the Mediterranean Sea and extends into the Black Sea.

Habitat

Ostrea edulis is associated with highly productive estuarine and shallow coastal water habitats on firm bottoms of mud, rocks, muddy sand, muddy gravel with shells and hard silt. In exploited areas, suitable habitat is/has been created in the form of 'cultch' - broken shells and other hard substrata.

Depth range

0-80 m

Identifying features

- Shell inequivalve, lower (left) valve convex and upper valve flat sitting within the lower.
- Periostracum thin, dark brown.
- Outer surface rough and scaly with concentric sculpture and fine radiating ridges.
- Yellowish or cream in colour with light brown or bluish concentric bands on the right valve.
- Hinge line without teeth in the adult.
- Adductor muscle scar white, or slightly discoloured.

Additional information

Also commonly known as the flat oyster and European oyster.

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Further information sources

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Biology review

Taxonomy

Phylum	Mollusca	Snails, slugs, mussels, cockles, clams & squid
Class	Bivalvia	Clams, cockles, mussels, oysters, and scallops
Order	Ostreida	Oysters, scallops & saddle oysters
Family	Ostreidae	
Genus	Ostrea	
Authority	Linnaeus, 1758	
Recent Synonyms	-	

Biology

Typical abundance	High density
Male size range	0.2-11 cm
Male size at maturity	5 cm
Female size range	0.2-11 cm
Female size at maturity	5 cm
Growth form	Bivalved
Growth rate	20 g/year
Body flexibility	None (less than 10 degrees)
Mobility	Sessile
Characteristic feeding method	Active suspension feeder
Diet/food source	Planktotroph
Typically feeds on	Suspended organic particles
Sociability	Gregarious
Environmental position	Epifaunal
Dependency	None.
Supports	Host The protozoan parasite *Bonamia ostreae*, and the parasitic copepod *Mytilicola intestinalis*.
Is the species harmful?	No

Biology information

- There is some evidence that reduced growth, weight and poor conditions are a consequence of high population densities (300 per square yard). Size and shape can be extremely variable. Because the oyster cements itself to the substratum, growth of neighbouring individuals may result in competition or space and distort the usual shell shape.
- Feeding is carried out by pumping water through a filter in the gill chamber removing suspended organic particles. Particulate matter which is resuspended from the bottom material by tidal currents and storms is likely to be an important food source (Grant *et al.*, 1990). Growth rates of *Ostrea edulis* are faster in sheltered sites than exposed locations, however this is thought to be attributed to the seston volume rather than flow speed or

food availability (Valero, 2006).
- Growth is quite rapid for the first year and a half. It then remains constant at around 20 grams per year before slowing down after five years. In the British Isles, the main growing season is from April to October. The oyster faces serious competition from the introduced species *Crepidula fornicata*, the slipper limpet. Brought over from the United States this species can occur in very high densities competing for space and food. The slipper limpet deposits pseudo faeces which forms 'mussel mud' changing the substratum and hindering settlement. Native oysters are preyed on by a variety of species including starfish and *Ocenebra erinacea*, the sting winkle or rough tingle. *Buccinum undatum*, the common whelk also feeds on oysters but not as exclusively as the sting winkle. *Urosalpinx cinerea*, the American oyster drill, was accidentally introduced to the British Isles with American oysters and lives on oyster beds feeding almost entirely on oyster spat.

Habitat preferences

Physiographic preferences	Estuary, Open coast, Ria / Voe, Sea loch / Sea lough
Biological zone preferences	Lower circalittoral, Lower eulittoral, Lower infralittoral, Sublittoral fringe, Upper circalittoral, Upper infralittoral
Substratum / habitat preferences	Bedrock, Cobbles, Gravel / shingle, Large to very large boulders, Mud, Muddy gravel, Muddy sand, Pebbles, Small boulders
Tidal strength preferences	Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Extremely sheltered, Moderately exposed, Sheltered, Very sheltered
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Depth range	0-80 m
Other preferences	No text entered
Migration Pattern	Non-migratory / resident

Habitat Information

The native oyster has also been introduced to and is cultivated in North America, Australia and Japan. Cultivated populations may be encouraged through the use of an artificial substratum (limed tiles) used preferentially for larval settlement. Oysters are found on a wide variety of substrata but typically where the seabed is hard. Can form into dense 'beds' of oyster shells.

Life history

Adult characteristics

Reproductive type	Protandrous hermaphrodite
Reproductive frequency	Annual protracted
Fecundity (number of eggs)	>1,000,000
Generation time	Insufficient information
Age at maturity	3 years
Season	June - September

Life span	5-10 years

Larval characteristics

Larval/propagule type	-
Larval/juvenile development	Planktotrophic
Duration of larval stage	11-30 days
Larval dispersal potential	Greater than 10 km
Larval settlement period	Insufficient information

Life history information

A lifespan of 5-10 years is probably typical as the majority of individuals in populations are 2-6 years old. However, they may reach in excess of 15 years old. Oysters are protandrous alternating hermaphrodites. This means that they start off as males producing sperm then switch to egg producing females, back to males and so on. The native oyster starts life as male, becoming mature at around 3 years of age. After spawning the oyster becomes a functional female. Larvae are seldom produced by oysters under 50 mm. Gamete maturation begins in March or April and is in part temperature dependent. Gametogenesis may be continuous in warmer conditions e.g. California. On the west coast of Ireland there is at least one spawning in each sexual phase during the summer. There may be some periodicity in spawning with peaks during full moon periods. Fecundity may be as high as 2,000,000 in large individuals. The eggs are around 150 microns in diameter. Eggs produced during the female stage are held in the gills and mantle cavity. The eggs are fertilized by sperm drawn in by the inhalant water flow used for feeding and respiration. The fertilized eggs are retained for 7-10 days until the veliger stage is reached, at which point they are released. This is called larviparous or incubatory development.

Sensitivity review

Resilience and recovery rates

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 (Korringa, 1951; Yonge, 1960). In some areas, there may be a small amount of natural settlement onto the lower shore of introduced species of oyster. Many populations are now artificially laid and then protected by Protection Orders (Fowler, 1999; cited in Tillin & Hull, 2013f). This species is found on a range of substrata; firm bottoms of mud, rocks, muddy sand, muddy gravel with shells and hard silt (Hiscock *et al.*, 2011; Tillin & Hull, 2013f). Large numbers of native oysters are uncommon in the UK and Ireland. However, there are significant populations in Strangford Lough, Lough Foyle and the west coast of Ireland; Loch Ryan in Scotland, Milford Haven in Wales; from Dawlish Warren, the Dart Estuary and the River Fal in the south-west England, and the River Crouch in east England.

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 – 5 years. 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 in preference 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).

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. *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 (Gubbay & Knapman, 1999; Bergman & van Santbrink, 2000; Sewell & Hiscock, 2005).

Spärck (1951) reported significant changes in population size due to recruitment failure. In years of bad recruitmen, 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 the 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 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).

Resilience assessment. Recovery is likely to be slow even within or from established populations. Larvae require hard substratum for settlement, with a significant preference for the shells of adults. Hence, where the adult population has been removed, especially where shell debris has also been removed, recovery is likely to be prolonged. Therefore, resilience to a pressure that removes part of the *Ostrea edulis* population is recorded as **'Low'** (10 -25 years for return) but if most of the population of *Ostrea edulis* is removed (i.e. resistance is **'None'**), the resilience is recorded as **'Very low'** (>25 years).

Note. The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally 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: High	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, and no individuals survived more than 7 days at 16 psu and 25°C, although these conditions rarely occurred in nature. No upper lethal temperature was found but 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* occurs from the Mediterranean to the Norwegian coast and is, therefore, 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 the 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.

Sensitivity assessment. The resistance of *Ostrea edulis* to the pressure at the benchmark is assessed as **'High'** with a consequent resilience of **'High'**. Therefore, this species is recorded as **'Not sensitive'** to the pressure at the benchmark level.

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

Hutchinson & Hawkins (1992) suggested that *Ostrea edulis* 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*.

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. Resistance is assessed as **'Medium'**, and resilience has been assessed as **'Low'** so that sensitivity of this species is recorded as **'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

Ostrea edulis is found in full to variable salinity waters and is unlikely to experience increased salinity waters. Hypersaline 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 recorded.

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.

Sensitivity assessment. *Ostrea edulis* can be found in both fully marine and variable salinity regimes. If a salinity regime were to become 'reduced' then *Ostrea edulis* may be adversely affected by the decrease in salinity. *Ostrea edulis* could 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 species. Therefore, resistance has been assessed as **'Medium'** and resilience as **'Low'**, so that a sensitivity of **'Medium'** is recorded at the benchmark level.

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

Ostrea edulis is found in areas with' Very Weak' (negligible), and 'Weak' < 1 knot (<0.5 m/sec.) tidal flows. 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 oysters 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 but could improve the availability of suspended particles on which oysters feed. The latter of which is most likely to have the greatest impact on individual oysters. 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, after which any further increase is not of any benefit.

Reproductive success and successful recruitment of *Ostrea edulis* may also be affected by a change in water flow. Recruitment is known to be sporadic and dependent on the hydrographic regime and local environmental conditions but enhanced by the presence of adults and shell material (Cole, 1951). An increase in water flow rate may interfere with the 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).

Sensitivity assessment. A change in water flow at the benchmark of this pressure it is unlikely to cause any effect on this species. It may remove fine sediments that accumulate in the bed but otherwise leave the hard substrata (gravel shell, pebbles, cobbles, etc.) to which the oysters are attached in place. Both the resilience and resistance of this species are assessed as **'High'** so that the species is assessed as **'Not sensitive'** at the benchmark level. However, an increase above the benchmark of this pressure could have a negative impact.

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 is 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 the emergence of *Ostrea edulis* is unlikely to result in the death of the oysters 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 upon return to aerated water, resulting in reduced growth and reproductive capacity.

Sensitivity assessment. *Ostrea edulis* is likely to resist an increase in emergence at the benchmark level. Both resistance and resilience are assessed as **'High'** so that *Ostrea edulis* is assessed as **'Not sensitive'** at the level of the benchmark.

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

Ostrea edulis occur at wave exposures ranging from very sheltered through to wave exposed conditions. The species is found from 0 –80 m in depth. The 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. *Ostrea edulis* may be replaced by other species 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 *Ostrea edulis*. Both the resilience and resistance of *Ostrea edulis* are assessed as **'High'** so that the species is assessed as **'Not sensitive'** at the benchmark level. However, an increase above the benchmark of this pressure could have a negative impact.

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 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.

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). Overall, hydrocarbon contamination would probably affect growth rates of juveniles and adult *Ostrea edulis*.

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). 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*.

While the 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. *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' was found.

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: Medium A: Medium C: Medium	High Q: High A: High C: Medium	Not sensitive Q: Medium 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).

Lenihan (1999) reported that *Crassostrea virginica* could withstand hypoxic conditions (< 2mg O^2 /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 of 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 the mass mortality of oysters (Lenihan, 1999).

Sensitivity assessment. *Ostrea edulis* is probably not affected by de-oxygenation at the level of the benchmark. Therefore, resistance and resilience are assessed as **'High'**, and *Ostrea edulis* is assessed as **'Not sensitive'** at the benchmark level.

Nutrient enrichment	High Q: High A: Medium C: Medium	High Q: High A: Medium 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 microalgal blooms (Bricker *et al*., 1999, 2008).

Moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material, is likely to increase food availability for suspension feeders such as *Ostrea edulis.* However, long-term or high levels of nutrient 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.

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 the possible proliferation of potentially toxic or nuisance species (OSPAR, 2009b).

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 algae decompose, especially in sheltered areas with little water movement where this *Ostrea edulis* is often found.

Sensitivity assessment. A slight increase in nutrients may enhance food supply to *Ostrea edulis* and increase growth rates in the species. And at the pressure benchmark that assumes compliance with WFD criteria for good status, there shouldn't be a negative impact on this species. Therefore the resistance and resilience have been assessed as **'High'**, resulting in an assessment of **'Not Sensitive'**.

Organic enrichment	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

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 microalgal 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.

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

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 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

Ostrea edulis can be found on top of a variety of sediment types including gravels, sand and mud, small boulders and bedrock. Therefore, if rock or an artificial substratum were to be replaced with a sedimentary substratum individual *Ostrea edulis* could theoretically also survive in this situation. But large populations of *Ostrea edulis* as beds occur on sediment and would be lost as a result of a change in seabed type. Therefore, resistance is likely to be **'Low'**, resilience **'Very Low'** (permanent change) and sensitivity is assessed as **'High'**.

Physical change (to another sediment type)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Ostrea edulis occurs on a range of sediment types and hence are not considered sensitive to change in folk class. Resistance and resilience are, therefore, assessed as **'High'** resulting in this species 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 substratum which provides a point of attachment for larvae.

Sensitivity assessment. The resistance to the removal of the substratum is **'None'**. The resilience is probably **'Very low'**.

Abrasion/disturbance of the surface of the substratum or seabed	Low	Low	High
	Q: High A: Medium C: Medium	Q: High A: High C: Medium	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 fishing mortality 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). 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 bed. The flatter bed is more susceptible to siltation and hypoxia in some water bodies (Woolmer *et al.*, 2011). 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.

Sensitivity assessment. *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. Therefore, resistance has been assessed as **'Low'**, and resilience is assessed as **'Low'**. Hence, the sensitivity of the species' is assessed as **'High'**.

Penetration or disturbance of the substratum subsurface	Low	Low	High
	Q: High A: Medium C: Medium	Q: High A: High C: Medium	Q: High 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 *Ostrea edulis* 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 subsurface disturbance will be to displace, damage and remove individuals. Therefore, resistance is assessed as **'Low'**. Resilience is assessed as **'Low'** and sensitivity is, therefore, assessed as **'High'**.

Changes in suspended solids (water clarity)

Resistance	Resilience	Sensitivity
Low	Low	High
Q: High A: Medium C: Medium	Q: High A: High C: Medium	Q: High A: Medium C: Medium

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).

Oysters respond to an increase in suspended sediment by increasing pseudofaeces production with the 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.

Sensitivity assessment. A short-term increase in sedimentation is likely to have an impact on *Ostrea edulis*. *Ostrea edulis* has a coping 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. However, at the level of the benchmark, there will be mortality at as the level of sediment in the water column will exceed that of what the organism can survive. With the change in the benchmark for a year, there will likely be complete mortality. Therefore, resistance and resilience are assessed as **'Low'** and a sensitivity is assessed as **'High'**.

Smothering and siltation rate changes (light)

Resistance	Resilience	Sensitivity
Low	Very Low	High
Q: High A: High C: Medium	Q: High A: High C: Medium	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). Smothering by 5 cm of sediment would prevent the flow of water through the oyster that permits respiration, feeding and removal of waste. *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 the 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.

Sensitivity assessment. *Ostrea edulis* is unlikely to survive this pressure at the benchmark level and deposited sediment is likely to interfere with subsequent recruitment. As filter feeders that are permanently attached to the substratum, they would be unable to borrow up to the surface. In the low energy environments in which populations of this species develop (i.e. weak water flow, sheltered from wave action, or at greater depths in moderately wave exposed conditions), the deposited sediment is likely to remain for several tidal cycles, depending on local hydrography. Therefore, resistance to the pressure is probably **'Low'**, resilience is **'Low'** and the species 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 *Ostrea edulis* with a thick layer of fine materials. *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. A deposit of 30 cm of material is likely to remain for a longer period of time than 5 cm (see above), Therefore, resistance to the pressure is probably **'None'** and resilience **'Very low'** so that sensitivity is assessed 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

'Not assessed'.

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

No evidence was found.

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

Ostrea edulis does not have hearing perception but vibrations may cause a reaction, e.g. valve closure. But it is unlikely to be affected by underwater noise from passing vessels etc.

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

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 species. However, prevention of light reaching the seabed may affect *Ostrea edulis* indirectly through changes in phytoplankton abundance and primary production.

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

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

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

'Not relevant'.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

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*) has 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 *Ostrea edulis*. Although *Ostrea edulis* may be translocated, **'No evidence'** was found on which to base an assessment.

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 to beds of *Ostrea edulis*. This species was introduced with the American oyster between 1887 and 1890 and became a serious pest on oyster beds. *Crepidula fornicata* competes for space with oysters, 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*.

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*., 2010). This species can colonize a range of substrata, and has been found on commercial oyster lays on the south coast of England. There are no studies on the effects of *Didemnum vexillum* on *Ostrea edulis*. However, it is likely that if *Ostrea edulis* were to be smothered by this species there could be negative impacts.

Sensitivity assessment. There is a chance that an INIS might invade the same habitats as those within which *Ostrea edulis* is found. Depending on which INIS species is introduced, *Ostrea edulis* may remain. 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 habitat is likely to change. Therefore, 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, and trematodes, while annelids and copepods may be parasites. 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 oyster's vulnerability to predation and physical damage, whereas *Polydora hoplura* causes shell blisters. Boring sponges of the genus Cliona may bore the shell of oysters and cause 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 1920-21, from which many populations did not recover (Yonge, 1960). Another protozoan parasite *Marteilia refingens*, present in France has not yet affected stocks in the British Isles. The copepod parasite of mussels, *Mytilicola intestinalis*, has also been found to infect *Ostrea edulis* and has the potential to cause 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 (a bacterial infection that can invade every tissue) in Pacific oysters (*Magallana gigas*) and *Ostrea edulis* (Forrest *et al*., 2009).

The protistan parasite *Bonamia ostrea* is a serious threat to *Ostrea edulis* in the UK (Laing *et al*., 2005, cited in Woomer *et al.* 2011). *Bonamia ostrea* has caused mortality of *Ostrea edulis* throughout northern Europe (France, the Netherlands and Spain) and Iceland and England after its accidental introduction in 1980's and resulted in a further reduction in oyster production (Edwards, 1997). Disease events reduced 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. Therefore, resistance and resilience have been assessed as **'Low'** and sensitivity as **'High'**.

Removal of target species	None Q: High A: Medium C: Medium	Very 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 species 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, and outbreaks of disease 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). For example, 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 and 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 scarcity 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 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 permanently attached to the substratum once they have settled from larvae. Therefore, resistance is assessed 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'** so that sensitivity is assessed as **'High'**.

Removal of non-target species	None Q: Medium A: Medium C: Medium	Very Low Q: High A: High C: Medium	High Q: Medium A: Medium C: Medium

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. *Ostrea edulis* could easily be incidentally removed from its habitat as by-catch when other species are being targeted.

Sensitivity assessment. The resistance to removal is **'None'** due to the inability of *Ostrea edulis* to evade collection. The resilience is **'Very low'**, with recovery only being able to begin when the harvesting pressure is removed altogether. Therefore sensitivity is assessed as **'High'**.

Importance review

Policy/legislation

UK Biodiversity Action Plan Priority	✓
Species of principal importance (England)	✓
Species of principal importance (Wales)	✓
Scottish Biodiversity List	✓
OSPAR Annex V	✓
Features of Conservation Importance (England & Wales)	✓

Status

National (GB) importance	Not rare/scarce	**Global red list (IUCN) category**	-

Non-native

Native	Native		
Origin	-	**Date Arrived**	-

Importance information

Native oyster fisheries are subject primarily to UK shellfisheries conservation legislation; the species is not named in any national or international nature conservation legislation or conventions. However, *Ostrea edulis* is included in a Species Action Plan under the UK Biodiversity Action Plan (Anon, 1999b) and naturally occurring native oyster beds are a nationally scarce habitat (see IMX.Ost).

Commercial native oyster transplantation has been recorded as a dispersal mechanism for non-native species. Oysters exported for market to the Netherlands from Britain may have attached to them plants of wireweed *Sargassum muticum*. The copepod mussel parasite *Mytilicola intestinalis* has also been recorded in native oysters on the S.W. and E coasts of Britain. Infection of oysters does not readily occur in the presence of mussels. Infection levels of up to 9.5 percent and 4 parasites per oyster have been recorded. Translocations of oysters could serve as a dispersal mechanism for this parasite into areas where it currently does not occur. The copepod can breed in female stage oysters larger than 50 mm. Infestation is unlikely to occur in oysters less than 15 mm. Consequently the maximum size limit for transported oyster seed has been set at 12 mm. A parasitic protozoan, *Bonamia ostreae*, causing the disease Bonamiasis has caused massive mortalities in France and has been introduced to some English populations. Care is required to prevent the infection of British Isles populations with the parasitic protozoan *Marteilia refringens* which is present in other European countries. There is a closed season from 14 May to 4 August during the main spawning season. Efforts are being made to reintroduce oysters to old, now derelict grounds. Settlement areas have been degraded by species such as *Crepidula fornicata*.

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