Fan mussel (*Atrina fragilis*)

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

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Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/species/detail/1157]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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Adult *Atrina fragilis* embedded in sea bed.
Photographer: Sue Scott

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	Dr Harvey Tyler-Walters & Catherine Wilding	**Refereed by**	Dr Dan Minchin
Authority	(Pennant, 1777)		
Other common names	-	**Synonyms**	*Atrina pectinata* (Linnaeus, 1767), *Pinna fragilis* (Pennant, 1777), *Pinna pectinata* (Linnaeus, 1767)

Summary

Description

One of Britain's largest and most threatened molluscs. It has a light golden or yellow-brown to dark brown shell reaching 30-48 cm long. The shell is triangular, tapering to a point, thin and brittle, making it very fragile. Fan mussels live with their pointed end embedded in sediment, attached to small stones or shells by abundant fine byssal threads. Between one and two-thirds of the shell is usually buried in the sediment. The posterior (broad) end protrudes from the surface of the sediment and may support growths of sea anemones, barnacles, hydroids and sponges. In the UK, it is often solitary but populations occur as small groups or patches of individuals forming small beds.

Recorded distribution in Britain and Ireland

Most recent records are from Scotland in deep water around the Shetland Isles and Orkney, and the west coast of Scotland, with scattered records from north-east Scotland, the south coast of England, the Channel Isles, Pembrokeshire in south Wales and Northern Ireland.

Global distribution

Recorded from north Scotland down to Mauritania, including the Iberian Peninsula, and into the Mediterranean.

Habitat

Lives embedded in sublittoral fringe and subtidal muds, sandy muds or gravels.

Depth range

Sublittoral fringe to 400m

Identifying features

- Large (30-48 cm in length by half that wide), triangular, thin and fragile shell tapering to a point.
- Shell with conspicuous concentric growth and disturbance lines with 8-12 low, smooth, wavy ridges radiating from the beaks (umbones).
- Occasional fluted spines.
- Shell colour light yellow-brown to darker brown or chestnut in colour.
- Inside of shell glossy (partly nacreous) with very dissimilar muscle scars, largest scar in the middle of shell valve.
- Valves gape at the posterior (broad) end.
- Byssus fine and abundant.
- Shell margin smooth but often fragmented at the posterior end.
- Lives with pointed anterior end embedded in muds, sandy mud or gravel, attached to small stones or shell fragments by byssus with between one or two-thirds of the shell below the sediment surface.

Additional information

According to Montagu (1803), the fan mussel was known for its silky byssus from which expensive gloves and stockings were once made. Montagu (1803) also states that shells were historically brought up from trawls off the Eddystone, Plymouth, and also taken by fishermen from Torbay and on the Dorset coast.

Information on the biology of *Atrina fragilis* is limited (Šimunović *et al.*, 2001; Solandt, 2003; Allen, 2011; Fryganiotis *et al.*, 2013). The following review draws on information from other species of *Atrina* and *Pinna* often from outside the UK. Readers should note that *Atrina fragilis* was synonymised with *Atrina pectinata* until recently (Huber & Gofas, 2017). *Atrina pectinata* is now recognised to be restricted to the Indo-Pacific, although many species of *Atina* and *Pinna* are 'cryptic', i.e. are difficult to distinguish based on morphology (Lemer *et al.*, 2014).

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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	Pinnidae	
Genus	Atrina	
Authority	(Pennant, 1777)	
Recent Synonyms	Atrina pectinata (Linnaeus, 1767)Pinna fragilis (Pennant, 1777)Pinna pectinata (Linnaeus, 1767)	

Biology

Typical abundance	Very low density
Male size range	30-48 cm
Male size at maturity	Unknown
Female size range	30-48 cm
Female size at maturity	Unknown
Growth form	Bivalved
Growth rate	ca 3-4cm/year
Body flexibility	None (less than 10 degrees)
Mobility	Burrower
Characteristic feeding method	Active suspension feeder
Diet/food source	Planktotroph
Typically feeds on	Phytoplankton
Sociability	Gregarious
Environmental position	Infaunal
Dependency	Independent.
Supports	Host Commensal *Pinnotheres pinnotheres* (pea crab) and *Capulus ungaricus* (Hungarian hat shell).
Is the species harmful?	See additional information This species may become toxic due to the accumulation of toxins during blooms of toxic algae.

Biology information

Anon (1999c) suggested that growth is relatively slow (ca 3 -4 cm/year) based on annular growth rings in specimens from Valentia Bay, Ireland. This data suggested that large specimens were at least 10-12 year old (Solandt, 2003). Bulter *et al*. (1993) noted that the growth of *Pinna bicolor* was indeterminate, rapid when small and slow after 2 years of age. For example, the growth rate of *Pinna nobilis* in the Mediterranean was observed to vary between sites, with some popualtions growing at 9 cm/yr and others at 6-7 cm/year. Papoutsi & Galinou-Mitsoudi (2010) reported a very low growth rate in *Atrina pectinata* in the Thermaikos Gulf (Greece) with juveniles reaching

4.6 cm at 2-4 months of age and adults reaching 37.5 cm at 32 years of age. However, Fryganiotis *et al.* (2013) reported that specimens caught in the Thermaikos Gulf) ranged from 7-16 years of age at lengths of 15-34 cm respectively, and calculated an annual growth rate of 2.6 cm/yr. [Note that the *Atrina pectinata* of Papoutsi & Galinou-Mitsoudi (2010) are presumably *Atrina fragilis*]. It is likely that growth rates in fan mussels vary with location, and are dependent on temperature, food supply.

The shell margin is easily damaged to produce sharp edges. These edges may cut the feet of bathers (Anon 1999c). However, fan mussels rapidly repair shell damage (Yonge, 1953).

Community interactions
Fan mussel communities have been poorly studied in the UK and information is only available from the Mediterranean, South Australia and the USA. Mollusc shells are often important settlement substrata for sessile organisms, or shelters/nest sites for mobile benthic animals in marine soft sediments (Kuhlmann 1998). The resource availability of shells may affect the population dynamics of these species. For example, *Pinna bicolor* hosts a species rich epifauna (Kay & Keough, 1981; Ward & Young, 1983). In St Joseph Bay, Florida, shells of dead *Atrina rigida*, predated by the horse conch, provide shelter for crabs, fish and octopus and were used as 'nests' by blennies, clingfish and toadfish (Kuhmann, 1997).

The presence of burrowing bivalves may also alter small scale flow dynamics, as is the case with *Atrina zealandica* (Nikora *et al.*, 2002). However *Atrina zealandica* occurs in far greater densities than UK examples of *Atrina fragilis*. It has been found that the distance between individuals of *Atrina zealandica* affects the associated benthic macrofauna (Hewitt *et al.*, 2002). The settlement of biodeposits (faeces and pseudofaeces) from *Atrina zealandica* is likely to have localised effects on benthic community structure (Miller *et al.*, 2002). The same may be true of *Atrina fragilis*, although these effects are likely to be reduced due to far lower densities. Pseudofaeces from pen shells results in biodeposits that reduce the variability of nematode meiofauna in *Atrina zealandica* beds (Warwick *et al.* 1997).

Habitat preferences

Physiographic preferences	Enclosed coast / Embayment, Offshore seabed, Ria / Voe
Biological zone preferences	Lower circalittoral, Lower infralittoral, Sublittoral fringe, Upper circalittoral, Upper infralittoral
Substratum / habitat preferences	Coarse clean sand, Fine clean sand, Gravel / shingle, Mixed, Mud, Muddy gravel, Muddy sand, Sandy mud
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Sheltered, Very sheltered
Salinity preferences	Full (30-40 psu)
Depth range	Sublittoral fringe to 400m
Other preferences	No text entered
Migration Pattern	Non-migratory / resident

Habitat Information

Distribution

Specimens occur as solitary individuals or localised patches of small groups of individuals.

Atrina fragilis was recorded in *Zostera* sp. beds in the Isles of Scilly. However, specimens have not been found since the *Zostera* sp. beds were lost (Turk 1982; Turk & Seaward, 1997). This species was more common in scallop areas in the early 1900s. Presumably trawling and dredging of these formerly populated regions is the reason for the decline of this species (Minchin pers. comm.). Dredging of a *Pecten maximus* bed off Glengad Head, Ireland, after 1975, removed many live specimens of *Atrina fragilis* in scallop dredges and the population of fan mussels is thought to have been destroyed by subsequent dredging (Anon 1999c).

Solandt (2003) described two 'hotspots' for *Atrina fragilis* in UK waters; in Scotland and south-west coast of Cornwall. Solandt (2003) also noted that in recent years (the 1990s onwards) more records of *Atrina fragilis* were obtained from deep water. For example, records in the Western approaches of the English Channel were at ca 100 m deep and 50 km offshore. In Scotland considerable populations were found in deep tidal waters of The Minch and the Sound of Skye and in the waters between John O'Groats and the Shetland Isles. Similarly, Šimunović *et al.* (2001) found that *Atrina fragilis* was most abundant at a depth of 25-50 m but was also found at ca 250 m in the Adriatic. *Atrina fragilis* was also records from Melville Knoll and Haddock Bank sea mounts, at depths of 50 m and 200 m ca 50 miles south-west of the Isles of Scilly (Solandt, 2003). In addition, the largest known area of fan mussels in the UK, in the Sound of Canna, covered an area of at least 170 ha and the densest patches were estimated to be 2 -4 /m^2 where the fan mussels occurred in clumps or scattered individuals at 102 -274 m (Howson *et al.*, 2012).

Nevertheless, the species has declined in abundance in the last 100 years especially in inshore waters (Solandt, 2003). It was once regularly caught in trawls in the Celtic Sea with anecdotal records of large individuals and 'decks covered with fragments of their shells' (Solandt, 2003).

Habitat preferences

Atrina fragilis is recorded from a variety of sediment types in UK waters. In the Mediterranean, dense populations were recorded from sandy bottoms with a mixture of terrigenous ooze (detritus of terrestrail origin) at a depth of 30 - 50 m (Šimunović *et al.*, 2001; Fryganiotis *et al.*, 2013). The species is known from weak to moderately strong currents. For example in Knightstown, Valentia Island, the population is exposed to >2 knots on spring tides (Dan Minchin pers. comm.). Although usually found at full salinities it may be exposed to reduced or variable salinities for brief periods (Dan Minchin pers. comm.).

Life history

Adult characteristics

Reproductive type	Gonochoristic (dioecious)
Reproductive frequency	No information
Fecundity (number of eggs)	Insufficient information
Generation time	Insufficient information
Age at maturity	Insufficient information
Season	Insufficient information
Life span	20-100 years

Larval characteristics

Larval/propagule type	Veliger
Larval/juvenile development	Planktotrophic
Duration of larval stage	No information
Larval dispersal potential	Greater than 10 km
Larval settlement period	Insufficient information

Life history information

Atrina fragilis is assumed to be long lived due to its large size. Butler *et al.* (1993) report that the related Mediterranean genus *Pinna nobilis* may live up to 18 years. Solandt (20030 suggested that its lifespan was 10-12 years based on growth estimates in the UK. However, populations of *Atrina fragilis* in the Adriatic were composed of individuals ranging between 7 and 16 years, based on growth rings (Fryganiotis *et al.*, 2013) and between 7 and 32 years, based on adductor muscle scars (Papoutsi & Galinou-Mitsoudi, 2010).

Dispersion is assumed to be possible over large distances due to the pelagic life history. Hiscock *et al.* (2011) noted that *Atrina fragilis* larvae were found in hauls in the middle of the English Channel, and suggested that their dispersal range was high. Similarly, the specimens of larvae studied by Allen (2011) were recovered from plankton samples taken at a depth of 150-200 m. However, Butler *et al.* (1993) mention evidence for genetic population subdivision in *Pinna bicolor* within the Gulf of St Vincent in South Australia, which suggests that effective dispersal is lower than expected. Fertilization is external and dependant on proximity of other individuals, and factors including water movement. When populations of *Pinna* become very sparse, as is the case in the UK, fertilization failure is likely to be significant (Anon, 1999c; Butler *et al.*, 1993). Recruitment is likely to be sporadic due to variable larval survival and irregular, limited dispersal. Dispersal between different patches is likely to be variable (Anon, 1999c).

Sensitivity review

Resilience and recovery rates

Pen shells (fan mussels) are vulnerable to over-exploitation due to their long life, slow growth, limited reproductive output and sporadic recruitment (Butler *et al.*, 1993). Rapid growth and rapid shell repair in Pinnids suggest high metabolic demand, that may result in reduced gamete production (Anon 1999; Butler *et al.*, 1993), consistent with a long-lived species. Larval dispersal may be limited or irregular and larval survival variable (Butler *et al.*, 1993). Fertilization efficiency in patchy populations of low density may also be low as individuals may be too far apart to reproduce (Anon, 1999c; Hiscock *et al.*, 2011). Therefore, with the exception of embayments and inlets where larvae may be trapped, recruitment of *Atrina fragilis* is poor and variable in comparison with other bivalve species (Anon, 1999c). However, surviving adults increase the possibility of fertilization and local recruitment. Anon (1999c) suggested that changes in factors that shorten the adult life of this species cannot be compensated for by an immediate reproductive response and recruitment.

In the Adriatic, Šimunović *et al.* (2001) concluded that the resident population of *Atrina fragilis* were self-sustaining in spite of trawl fishing and occasional hypoxic events, based on experimental bottom trawls in 17 cruises of the PIPETA Expedition between 1982 and 1994. These cruises recorded *Atrina fragilis* from 20% of 780 hauls in that period and averaged between ca 1 to ca 5000 individuals per km^2. In addition, numerous hauls included both juveniles and adults (Šimunović *et al.*, 2001). Fryganiotis *et al.* (2013) and Papoutsi & Galinou-Mitsoudi (2010) also reported a range of size classes, including juveniles, from the Thermaikos Gulf, Adriatic, which indicated that the populations studied were recruiting.

However, Fryganiotis *et al.* (2013) recorded a density of 0.03 to 6.27 individuals/km in the Thermaikos Gulf, in the Adriatic. However, Fryganiotis *et al.* (2013; Fig 2) reported that the density of fan mussels in trawled areas (ca 0.03 individuals /km) was sparse compared to the areas in which bottom trawling was prohibited for 25 years (ca 5.5 individuals /km). Fryganiotis et al. (2013) suggested that 25 years was probably a time period that allows population recovery in this species. The largest known area of fan mussels in the UK, in the Sound of Canna, covered an area of at least 170 ha. The densest patches were estimated to be 2 -4 /m^2 (but ranged to 1-2 m^2) where the fan mussels occurred in clumps or scattered individuals (Howson *et al.*, 2012).

Nevertheless, the species has declined in abundance in the last 100 years especially in inshore waters (Solandt, 2003). It was once regularly caught in trawls in the Celtic Sea with anecdotal records of large individuals and 'decks covered with fragments of their shells' (Solandt, 2003). The decline in the Mediterranean (Richardson *et al.*, 1999) and its loss from inlets in south-west England (Anon 1999c) suggest that any recovery from disturbance would be slow.

Resilience assessment. The decline of *Atrina fragilis* in UK inshore waters and the Mediterranean over the last hundred years suggests that recovery is slow (Richardson *et al.*, 1999; Solandt, 2003). Their long-life, slow growth, limited reproductive output, low fertilization efficiency in sparse populations, and sporadic recruitment (Butler *et al.*,1993; Anon, 1999c) is also likely to hamper their ability to recover from disturbance and population mortality. Juveniles were only recorded in studies of populations in the Thermaikos Gulf, Adriatic and no information on the dynamics of UK populations was found. The large area of fan mussels in the Sound of Canna may have resulted from a single successful recruitment event. The increased numbers of records from deep waters could suggest that *Atrina fragilis* is under-recorded in offshore areas, which themselves could provide a reservoir for recruitment to the inshore areas but there is no evidence to support this idea. Nevertheless, recruitment to and recovery of populations is likely to be prolonged. Therefore, recovery from any loss of the population (i.e. a reduction in the extent or abundance, resistance is 'Medium' or 'Low') may take up to 25 years where the populations are sparsely distributed (e.g. in the UK). Hence, a resilience of **'Low'** will be recorded. However, where the population is severely reduced in abundance or extent (i.e. resistance is 'None') a resilience of **'Very low'** will be recorded.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: Low A: NR C: NR	Low Q: Medium A: Medium C: Medium	Medium Q: Low A: Low C: Low

No information on temperature tolerance in *Atrina fragilis* was found, although it has been suggested that changes in seawater temperature are likely to affect larval recruitment patterns (Anon., 1999c). A tropical pen shell *Atrina maura* was found to reach maturity more quickly at higher temperatures, taking only one month (normal maturation at lower temperatures of 20 °C takes two months). However, with higher temperatures, oocytes are of poor quality than at cooler temperatures (Rodriguez-Jaramillo, 2001).

Subtidal species such as *Atrina fragilis* are likely to exhibit lower temperature tolerance than intertidal species and are not likely to be resistant of rapid temperature change indicated in this benchmark. However, they occur from the Mediterranean to the Shetland Isles and are probably resistant to the range of temperatures that occur within that range.

Therefore, *Atrina fragilis* is probably resistant of a long-term change in temperature of 2°C for a year (see benchmark). But shallow subtidal and sublittoral fringe populations are likely to be adversely affected by short-term changes in temperature of 5°C for a month (see benchmark). Therefore, a resistance of **'Medium'** is recorded to represent the loss of the upper shore or shallow populations, albeit with 'Low' confidence. Resilience is probably **'Low'** and sensitivity is assessed as **'Medium'**.

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

No information on temperature tolerance in *Atrina fragilis* was found, although it has been suggested that changes in seawater temperature are likely to affect larval recruitment patterns (Anon., 1999c). A tropical pen shell *Atrina maura* was found to reach maturity more quickly at higher temperatures, taking only one month (normal maturation at lower temperatures of 20 °C takes two months). However, with higher temperatures, oocytes are of poor quality than at cooler temperatures (Rodriguez-Jaramillo, 2001).

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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

Atrina fragilis occurs subtidally at full salinity but shallow subtidal populations may experience variable salinity. Dan Minchin (pers. comm.) suggested that *Atrina fragilis* may be exposed to reduced or variable salinities for brief periods. A tropical pen shell *Atrina maura*, was found to have a wide range of halotolerance, from 16-50 (Leyva-Valencia *et al.*, 2001). *Atrina fragilis* is probably not resistant of changes in salinity. However, no information on the effects of hypersaline conditions or effluent on this or related species was found, and no assessment was made.

Salinity decrease (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

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

Atrina fragilis is known from weak (<0.5 m/s) to moderately strong currents (0.5-1.5 m/s), for example in Knightstown, Valentia Island the population is exposed to >2 knots on spring tides (Dan Minchin pers. comm.). Increased water flow (i.e. to 'strong', 1.5-3 m/s) could partly uncover adults and is likely to remove some individuals from the substratum, which would not then be able to survive to re-establish themselves. Changes in current patterns are also likely to affect larval recruitment (Anon., 1999c). However, an increase of 0.1-0.2 m/s for one year (the benchmark) may not be significant. A decrease in flow to 'very weak' or 'negligible' may be detrimental as water flow is important to provide a food supply for suspension feeders, as well as oxygenate the water column, especially in isolated waters. A reduction is food supply may well decrease growth and reproduction in this species, although as the species is long-lived, a change for one year (see benchmark) may not result in mortality. Therefore, a resistance of **'High'** is recorded, albeit with 'Low' confidence. Hence, resilience is **'High'** and the species is assessed as **'Not sensitive'** at the benchmark level.

Emergence regime changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The majority of *Atrina fragilis* populations occur in the subtidal and in deep water and changes in emrgence are **Not relevant**. However, *Atrina fragilis* has been recorded from the sublittoral fringe and shallow subtidal. It is possible that a sublittoral fringe population could be exposed to increased emergence, in which case the affected population would probably die.

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

Atrina fragilis occurs in sheltered or very sheltered waters (Anon 1999c; Butler *et al.* 1993) and can burrow into the substratum if partly uncovered by wave action or storms (Yonge 1953). However, prolonged increase in wave action could remove some individuals from the substratum, which would not then be able to survive to re-establish themselves. Juveniles may remove from sediment more easily than adults. Nevertheless, a change in significant wave height of 3-5% (the benchmark) is unlikely to be significant, especially as the depth of the population increases. Therefore, a resistance of **'High'** is recorded, with a resilience of **'High'** and this species is probably **'Not sensitive'** at the benchmark level.

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.

Anon (1999c) suggested that *Atrina fragilis* may be affected by pollutants such as TBT (tri-butyl tin). Reid & Brand (1989) describe kidney gigantism and nephroliths (calcium or iron granules) in *Pinna bicolor*. Their role in removing excess calcium or heavy metals and potential detoxification is unclear. Ward & Young (1983) examined changes in epifauna of *Pinna bicolor* due to heavy metal contamination in Spence Gulf, south Australia. They stated that *Pinna bicolor* was tolerant of high concentrations of heavy metals in sediments near a lead smelter and contained high body loads of heavy metals. The occurrence of populations of this species in heavy metal contaminated sediment suggests that it is not sensitive. However, the body burden of *Pinna bicolor* was not given and no citation provided for the information. The studied population may represent a localised adaptation.

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**.

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**.

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

Butler *et al.* (1993) state that *Pinna bicolor* and *Pinna nobilis* remain active at low oxygen concentrations (no value was given) and open their valves widely. Neither species stop pumping or respire anaerobically. Jaklin & Zahtila (1990, cited by Šimunović *et al.*, 2010) reported a mass mortality in the northern Adriatic due to an anoxic event in November 1989. Subsequent diver surveys in January 1990 found many empty shells of *Atrina fragilis* in an area previously populated by 1-2 fan mussels per m^2 but suggested that 10% of the population survived. Bivalves are generally resistant to hypoxia and can respire anaerobically. The limited evidence suggests that *Atrina fragilis* is likely to suffer significant mortality in hypoxic condition (e.g. below 2 mg/l) and severe mortality in anoxic conditions. Therefore, a resistance of **'Low'** is suggested. Resilience is probably **'Low'** and sensitivity is assessed as **'High'.**

Nutrient enrichment	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Pinnids are mainly found in sheltered oligotrophic (low nutrient) waters (Butler *et al.*, 1993), and they filter continuously, presumably an adaptation to low food availability. A small population of *Atrina fragilis* was recorded near a sewage discharge in Dingle Harbour (Dan Minchin pers comm.). An increase in nutrients is likely to increase phytoplankton production in the short-term, which may benefit larvae and juveniles. But excessive nutrient enrichment may lead to the development of algal blooms, and hypoxic conditions in the benthos (see deoxygenation above). Nevertheless, this species is probably **'Not sensitive'** at the benchmark level (resistance and resilience are **'High'**) set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014).

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

Pinnids are mainly found in sheltered oligotrophic (low nutrient) waters (Butler *et al.*, 1993), and they filter continuously, presumably an adaptation to low food availability. A small population of *Atrina fragilis* was recorded near a sewage discharge in Dingle Harbour (Dan Minchin pers comm.). Organic enrichment is likely to result in hypoxic sediment and an increase in opportunistic infauna, together with an increase in suspended sediments and siltation, which may be detrimental. However, *Atrina fragilis* is recorded from detritic bottoms with terrigenous ooze in the Adriatic (Fryganiotis *et al.*, 2013). Overall, the evidence was not adequate and no sensitivity assessment was made.

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

A change from sediment to hard rock substratum would result in loss of the habitat for this species. Therefore, resistance is assessed as **‘None’.** The change is defined as permanent so that resilience is assessed as **‘Very low’** and sensitivity is assessed as **‘High’.** Although no specific evidence is described, confidence in this assessment is ‘High’ due to the incontrovertible nature of this pressure.

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

The Pinnidae live embedded in soft substrata but with enough underlying gravel to provide attachment for their byssus threads (Yonge, 1953). *Atrina fragilis* has been recorded from a variety of sediment types e.g. muddy sands to clean sands, often mixed with gravels and shell (see habitat preferences above). For example, Fryganiotis *et al.* (2013) stated that this species was characteristic of 'detritic' bottoms, sandy bottoms and terrigenous ooze sediments, while Šimunović *et al.* (2001) reported that it was most abundant on sand-silt-clay sediments and clayey 'relict' sand. Howson *et al.* (2012) reported that the fan mussel bed in the sound of Canna occurred on mixed muddy sand with cobble, gravel, shell debris and occasional boulders but that one station with dense *Atrina fragilis* occurred on rippled sand with burrows. Therefore, *Atrina fragilis* is probably resistant of a change in one Folk class (see benchmark), and a resistance of **'High'** is recorded. Hence, resilience is **'High'** and the species is assessed as **'Not sensitive'** at the benchmark level.

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

Atrina fragilis lives buried in sediment, with about one third to one half of its shell length above the sediment surface, which, in adults, can be up to 10 -15 cm above the sediment surface. However, the removal of sediment to a depth of 30 cm is likely to remove the entire population of fan mussels in the affected area. Therefore, a resistance of **'None'** is recorded. Resilience is probably **'Very low'** so that sensitvity is assessed as **'High'**.

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

Atrina fragilis has a fragile shell, damaged easily by anchor impact, or trampling by bathers of fish predation. It is probably adapted to such damage as the mantle and ctendia can be withdrawn into the remainder of the shell, and the damaged edge of the shell can repair quickly, e.g. at ca 1 cm /day in *Pinna carnea* (Yonge, 1953; Solandt, 2003). *Atrina* can burrow vertically but cannot 'right' itself if removed from the sediment and laid on its side (Yonge, 1953). Specimens removed from the sediment by a passing trawl, mooring chain etc. are unlikely to be able to reburrow.

Scallop dredging and demersal trawling have been implicated in the decline in populations of this species (Anon, 1999c; Hall-spencer et al., 1999; Solandt, 2003; Šimunović et al., 2001; Fryganiotis *et al.*, 2013). Solandt (2003) noted anecdotal records where 'considerable fragments of *Atrina* shells were collected by scallop trawlers', and large individuals caught in the Celtic Sea in the 1970s with 'decks covered with the broken fragments of this species'. Solandt (2003) also reported anecdotal records from the diving community of considerable numbers of *Atrina fragilis* found in areas where scallop trawlers and dredgers cannot set gear. Rapido trawling for scallops (a form of beam trawl) in the Gulf of Venice resulted in the removal of organisms from the top 2 cm of sediment and an 87% reduction in *Atrina fragilis* abundance in the trawl tracks. Some specimens were speared on the trawl teeth and pulled from the sediment (Hall-Spencer *et al.* 1999). Anon (1999c) suggested that the destruction of a population of *Atrina fragilis* off Glengad Head, Ireland after 1975 was caused by scallop dredging. In the Adriatic queen scallop (*Aequipecten opercularis*) trawl fishery, *Atrina fragilis* incurred more damage as a result of the fishing and sorting process than any other species of bycatch (Pranovi *et al.*, 2001). In the Adriatic, Fryganiotis *et al.* (2013; Fig 2) reported that the density of fan mussels in trawled areas (ca 0.03 individuals /km) was sparse compared to the areas in which bottom trawling was prohibited for 25 years (ca 5.5 individuals /km).

Sensitivity assessment. The above evidence suggests that *Atrina fragilis* can survive low levels of abrasion e.g. trampling in the shallow sublittoral and possibly pots and creels that damage the exposed shell. However, any passing chains or gear that could remove individuals, or objects placed on the substratum temporarily (e.g. legs of jack-up barges) are likely to cause some mortality. Therefore, a resistance of **'Medium'** is suggested. Resilience is probably **'Low'** and sensitivity is assessed as **'Medium'.**

Penetration or disturbance of the substratum subsurface	None Q: High A: Medium C: Medium	Very Low Q: Medium A: Medium C: Medium	High Q: Medium A: Medium C: Medium

Atrina fragilis has a fragile shell, damaged easily by anchor impact, or trampling by bathers of fish predation. It is probably adapted to such damage as the mantle and ctendia can be withdrawn into the remainder of the shell, and the damaged edge of the shell can repair quickly, e.g. at ca 1 cm /day in *Pinna carnea* (Yonge, 1953; Solandt, 2003). *Atrina* can burrow vertically but cannot 'right' itself if removed from the sediment and laid on its side (Yonge, 1953). Specimens removed from the sediment by a passing trawl, mooring chain etc. are unlikely to be able to reburrow.

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Sensitivity assessment. The above evidence suggests that *Atrina fragilis* can survive low levels of abrasion. However, penetrative gear such as beam trawls, Rapido trawls and scallop dredges are likely to cause severe mortality. Therefore, a resistance of **'None'** is suggested. Resilience is probably **'Very low'** and sensitivity is assessed as **'High'.**

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

Pinnids are adapted to a sedimentary lifestyle and possess a unique ciliated waste canal for the removal of sediment from the mantle cavity (Yonge 1953). However, increased siltation will require increased metabolic demand on filtration and a likely decrease in growth and reproductive capacity. *Pinna bicolor* and *Pinna nobilis* occur in sheltered areas of low turbidity. However, juveniles settle in the boundary layer and grow rapidly to escape the high levels of sediment and it is likely that Pinnids are tolerant of suspended sediment. The absence of *Pinna* sp. from areas of severe sediment disturbance (Bulter *et al.* 1993) suggests that the populations in areas of high sediment availability will be adversely affected by increased siltation.

Thrush *et al.* (1999) demonstrated a decrease in the biochemical condition in *Atrina zealandica* with increasing sediment load in the Mahurangi Estuary, New Zealand. Ellis *et al.* (2002) examined the effects of the addition of sediment in laboratory experiments, at a range of turbidity treatments that represented the range of values (23-512 mg/l) experienced in the Mahurangi Estuary, where the normal background turbidity ranged from 12-90 mg/l but were much higher in storm associated resuspension of sediment or runoff from forestry. The initial addition of suspended sediment increased clearance rates, in the same way that increased seston (phytoplankton) was found to increase filtration rates (Ellis *et al.*, 2002; Safi *et al.*, 2007). Clearance rates increased with increasing suspended sediment until a threshold of ca 120 FTU (Formazin Turbidity Unit) at which clearance rates declined (Ellis *et al.*, 2002). Clearance rates continued to decrease over the duration of the experiment (12 days) in all of the sediment addition treatments. Negative effects on the condition of *Atrina zelandica* became apparent after only 3 days of exposure to increased suspended sediment levels, compared to controls with 'no' sediment added (Ellis *et al.*, 2002). In transplantation experiments, Ellis *et al.* (2002) found that *Atrina* transplanted to area closest to the mouth of the estuary (lower suspended sediment flux) improved in condition over the 3 months of the experiment. But *Atrina* transplanted to upper estuary sites (with high suspended sediment flux, equivalent to 108 g dry weight of sediment per month in sediment traps) lost condition. No *Atrina* occurred naturally at this upper estuary site, which may represent the upper limit of its tolerance of suspended sediment. *Atrina* also lost condition at intermediate sites (e.g. at 49 g dry weight of sediment per month) (Ellis *et al.*, 2002). It may be that *Atrina zelandica* found in areas with naturally high sediment loading are adapted to cope better with increases in suspended sediment than those from areas with lower background sediment concentrations. None the less, very large increases in suspended sediment are still likely to be detrimental to *Atrina zelandica* (Hewitt & Pilditch, 2004).

Sensitivity assessment. *Atrina* sp. are probably well adapted to a sedimentary habitat and the occasional resuspension of sediment due to storms, as they are able to cleanse themselves quickly.

However, even short-term (i.e. 3 day) increases in suspended sediment, similar to that created by storms and storm runoff, is likely to result in a loss of condition but not mortality. However, an increase in turbidity from, for example, 'clear' to 'intermediate' (100-300 mg/l) or turbid (>300 mg/l) for a period of a year (see benchmark) may be detrimental. Therefore, a resistance of **'Medium'** is recorded. Resilience is probably **'Low'** and sensitivity is assessed as **'Medium'.**

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

Atrina fragilis cannot burrow upwards through sediment (Yonge, 1953). However, one third to one half of the animal can protrude above the surface which, in adults, can be up to 10 -15 cm above the sediment surface. Therefore, adult specimens may not be affected by smothering by 5 cm of fine sediment (see benchmark). However, small or juvenile specimens may be smothered. Pinnids are adapted to a sedimentary lifestyle and exhibit a powerful exhalent current and a unique ciliated waste canal to remove sediment from the mantle cavity, as would be expected from occasional smothering due to storms (Yonge, 1953). Clearance of sediment from the mantle constitutes a metabolic cost that may reduce the reproductive ability (Butler *et al.*, 1993). Individuals are likely to cleanse themselves relatively quickly. However, small juveniles may be smothered and resistance is assessed as **'Medium'**. Resilience is probably **'Low'** and sensitivity is assessed as **'Medium'**.

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

Atrina fragilis cannot burrow upwards through sediment (Yonge, 1953). One third to one half of the animal can protrude above the surface which, in adults, can be up to 10 -15 cm above the sediment surface. Therefore, adult and juvenile specimens are likely to be smothered by 30 cm of fine sediment (see benchmark), which in sheltered conditions is likely to remain. Therefore, resistance is assessed as **'None'**. Resilience is probably **'Very low'** and 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

Not relevant. *Atrina fragilis* probably reacts to localised vibration but is unlikely to react to the noise from passing vessels etc.

Introduction of light or shading	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. *Atrina fragilis* is a suspension feeder, feeding on phytoplankton. Artificial light or localised shading is unlikely to alter phytoplankton productivity to any significant level, especially in deep waters and/or where currents supply food to the fan mussel.

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 the dispersal of larval stages or propagules. However, the dispersal of larval stages or propagules 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 interaction with bottom towed fishing gears and moorings are 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. *Atrina fragilis* probably reacts to localised shading but is unlikely to react to the visual disturbance from passing vessels etc.

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

No evidence of translocation, breeding or hybridization with other species was found.

Introduction or spread of invasive non-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

Crepidula sp. may have had some impact on near shore populations of *Atrina fragilis* on the south coast of England (Dan Minchin pers comm.). But no further evidence was found.

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

The Pinnids are parasitized by the pea crab (Pinnotheridae) (Yonge 1953). Butler *et al.* (1993) state that *Pinna bicolor* and *Pinna nobilis* harbour macroscopic commensals or parasites of unknown effect, although an unidentified parasitic microbe has been recorded as causing castration of *Pinna nobilis*. Any parasite is likely to reduce the condition of the host but no information on mortality rates (if any) was found.

Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

In Spain, pinnids may be collected for consumption, used as bait, or for use as souvenirs. In the Bay of Naples the byssus threads were historically used for making glues. In the Pacific, declines in production have occurred as a result of exploitation in other species of pen shell (Cardoza-Velasco & Maeda-Martinez, 1997). However, *Atrina fragilis* is not targetted by any commercial fishery in the UK.

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

Scallop dredging and demersal trawling have been implicated in the decline in populations of this species (Anon, 1999c; Hall-spencer et al., 1999; Solandt, 2003; Šimunović et al., 2001; Fryganiotis *et al.*, 2013). In the UK, *Atrina fragilis* was more common in scallop beds in the early 1900s than at present. Presumably trawling and dredging of these formerly populated regions is the reason for the decline of this species (Minchin pers. comm.). Dredging of a *Pecten maximus* bed off Glengad Head, Ireland, after 1975, removed many live specimens of *Atrina fragilis* in scallop dredges and the population of fan mussels is thought to have been destroyed by subsequent dredging (Anon 1999c). Solandt (2003) noted anecdotal records where 'considerable fragments of *Atrina* shells were collected by scallop trawlers', and large individuals caught in the Celtic Sea in the 1970s with 'decks covered with the broken fragments of this species'. Solandt (2003) also reported anecdotal records from the diving community of considerable numbers of *Atrina fragilis* found in areas where scallop trawlers and dredgers cannot set gear.

In the Adriatic queen scallop (*Aequipecten opercularis*) trawl fishery, *Atrina fragilis* incurred more damage as a result of the fishing and sorting process than any other species of bycatch (Pranovi *et al.*, 2001). In the Adriatic, Fryganiotis *et al.* (2013; Fig 2) reported that the density of fan mussels in trawled areas (ca 0.03 individuals /km) was sparse compared to the areas in which bottom trawling was prohibited for 25 years (ca 5.5 individuals /km). Rapido trawling (a form of beam trawl) for scallops in the Gulf of Venice resulted in the removal of organisms from the top 2 cm of sediment and an 87% reduction in *Atrina fragilis* abundance in the trawl tracks. Some specimens were speared on the trawl teeth and pulled from the sediment (Hall-Spencer et al. 1999). Pinnids in the Mediterranean are associated with seagrass beds, the removal of which has been linked to the decline in pinnid populations (Richardson *et al.* 1999).

Sensitivity assessment. The above evidence suggests that *Atrina fragilis* is vulnerable to demersal fisheries. Therefore, a resistance of **'None'** is suggested. Resilience is probably **'Very low'** and sensitivity is assessed as **'High'**.

Importance review

Policy/legislation

Wildlife & Countryside Act	Schedule 5, section 9
UK Biodiversity Action Plan Priority	✔
Species of principal importance (England)	✔
Species of principal importance (Wales)	✔
Northern Ireland Priority Species	✔
Scottish Biodiversity List	✔
Priority Marine Features (Scotland)	✔

Status

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

Non-native

Native	Native		
Origin	-	**Date Arrived**	-

Importance information

The legendary 'cloth of gold' was made from the long fine byssus threads of pinnids (Osing, 1968, Turk, 1982). Curiously, in past times, although seldom captured, many fishermen considered *Atrina fragilis* unclean, and returned it directly to the sea because the byssus was so similar to human hair that it was thought that they had consumed drowned sailors (Dan Minchin, pers comm.). Mediterranean *Pinna nobilis* may be taken for bait, consumption and for the curio trade. The byssus of pinnids was collected in Bay of Naples for making glues (Dan Minchin pers comm.). The community structure of UK fan mussel beds is poorly studied.

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