Great scallop (*Pecten maximus*)

MarLIN – Marine Life Information Network
Biology and Sensitivity Key Information Review

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Great scallop, *Pecten maximus*, and maerl.
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	Charlotte Marshall & Emily Wilson	**Refereed by**	Andy Beaumont
Authority	(Linnaeus, 1758)		
Other common names	-	**Synonyms**	-

Summary

Description

Both shell valves are fan shaped with an 'ear' on either side of the apex of the valve. The right valve is strongly convex and tends to be off-white, yellowish, or light brown in colour, often with bands or spots of darker pigment. The left valve is flat and is light pink to reddish brown in colour. *Pecten maximus* grows up to 15 cm long and both valves each have 15-17 radiating ribs.

Recorded distribution in Britain and Ireland

Recorded around most coasts of Britain and Ireland, with only scattered records from the east coast of Great Britain.

Global distribution

Pecten maximus occurs along the European Atlantic coast from northern Norway, south to the Iberian peninsula and has also been reported off West Africa, the Azores, Canary Islands and Madeira.

Habitat

Usually found in a shallow depression in the seabed. Prefers areas of clean firm sand, fine or sandy gravel and may occasionally be found on muddy sand. Distribution in this species is invariably patchy.

Depth range

10-110 m

Identifying features

- Flat left valve, right valve strongly convex.
- Right valve overlaps the left valve slightly along the margin.
- Ears equal, with a small byssal notch in right anterior ear.
- Right valve off-white, yellowish, or light brown, often with bands or spots of darker pigment, left valve light pink to reddish-brown.
- Up to 15 cm long, each valve with 15-17 broad, radiating ribs.

Additional information

Also known as the King scallop, Giant scallop, escallop and Coquille St. Jacques.

Listed by

Further information sources

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Biology review

Taxonomy

Phylum	Mollusca	Snails, slugs, mussels, cockles, clams & squid
Order	Pectinida	
Family	Pectinidae	
Genus	Pecten	
Authority	(Linnaeus, 1758)	
Recent Synonyms	-	

Biology

Typical abundance	Moderate density
Male size range	
Male size at maturity	
Female size range	Medium(11-20 cm)
Female size at maturity	
Growth form	Bivalved
Growth rate	See additional text
Body flexibility	None (less than 10 degrees)
Mobility	
Characteristic feeding method	Active suspension feeder
Diet/food source	
Typically feeds on	Seston including phytoplankton, especially single celled algae, particulate organic matter (POM), bacteria and other micro-organisms (Fegley *et al.*, 1992; Reitan *et al.*, 2002).
Sociability	
Environmental position	Epibenthic
Dependency	No text entered.
Supports	See additional information
Is the species harmful?	No

Biology information

Size

Pecten maximus are hermaphrodite and, therefore, there is no separate male and female size range or size at maturity. *Pecten maximus* grows up to 15 cm and will be at least 6 cm when sexually mature.

Recession

Pecten maximus normally lies recessed into slight hollows (recesses) in the seabed (Mason, 1983). Recessing is achieved through a series of powerful adductions (valve closures) where water is ejected from the mantle cavity and lifts the shell at an angle to the seabed so that subsequent water jets blow a hollow into the sediment (Brand, 1991).

Mobility

Swimming is generally limited to escape reactions. Experimental contact with different starfish species elicited distinct, energy adaptive types of response from *Pecten maximus*. Full swimming response was initiated only by extracts of *Asterias rubens* and *Astropecten irregularis* which prey on molluscs, while limited jumping or valve-closing responses were induced by non-predatory starfish (Thomas & Gruffydd, 1971).

Pecten maximus is capable of swimming by rapidly clapping the valves and expelling the water on either side of the dorsal hinge so that the scallop moves with the curved edge of the shell foremost (Thomas & Gruffydd, 1971). Jumping is achieved through the gradual relaxation of the adductor muscle followed by the rapid opening and closing of valves, which jump the scallop hinge forward (Thomas & Gruffydd, 1971).

Size and growth

Specimens of up to 21 cm have been recorded, although this is exceptional and the size range of scallops caught commercially is usually between 10 and 16 cm (Mason, 1983).
Scallop shells bear distinct and concentric annual growth rings. The shells also bear numerous regularly occurring concentric striae 0.1-0.3 mm apart which are also used to age the scallops (Mason, 1957). Minchin (2003) stated that it took between three and six years to attain 11 cm in shell length. The Minimum Landing Size (MLS) for this species in Britain and Ireland is 10-11 cm (depending on area) and growth to this size is usually achieved within four years (Brand *et al.*, 1991).
Growth rate can be affected by several factors including salinity, temperature, competition, water depth and food supply. For example, Laing (2002) found that the growth rate of spat grown at 13-21 °C was significantly lower at 26 psu than at 28-30 psu. Mason (1957) found that specimens from inshore, shallower waters typically displayed higher growth rates and maximum sizes than those from deeper waters. Even differences in growth rate between different grounds have been reported (Mason, 1983). Growth in *Pecten maximus* slows down or stops altogether in the winter, starts again in spring and continues through summer when it is most active. Growth also becomes slower in older individuals and consequently the growth rings become closer together and difficult to distinguish (Mason, 1957). In contrast to many other studies on bivalves, Beaumont *et al.* (1985) found no association between heterozygosity and size in this species, i.e. genetic factors are relatively unimportant compared to environmental controls on growth. However, they also suggested that genetic factors may be more important during the larval stage.

Eyes

Embedded among the bases of the sensory tentacles around the edge of the mantle are numerous tiny eyes (Mason, 1983). The eyes are a blue green colour no more than ca 1.5 mm in diameter. The eyes bear a superficial resemblance to the camera eyes of vertebrates and have a highly specialized retina (Wilkens, 1991). Light has both inhibitory and excitatory effects and scallops will swim, orient themselves or close their shell in response to shadows or movement (Wilkens, 1991).

Public health

Campbell *et al.* (2001) reported that, in July 1999, the Amnesic Shellfish Poisoning toxin, Domoic Acid (DA), was found in *Pecten maximus* at levels exceeding the regulatory limit of 20 µg DA / gram across large areas of northern and western Scotland. The risk of human illness resulting from consuming toxic scallops is, according to Shumway & Cembella (1993, cited in Campbell *et al.*, 2001), a significant threat to both public health and the shellfish industry.

Habitat preferences

Physiographic preferences	Open coast, Offshore seabed, Sea loch / Sea lough, Enclosed coast / Embayment
Biological zone preferences	Lower circalittoral, Lower infralittoral, Upper circalittoral
Substratum / habitat preferences	Coarse clean sand, Fine clean sand, Gravel / shingle, 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	Exposed, Extremely sheltered, Sheltered, Very sheltered
Salinity preferences	Full (30-40 psu)
Depth range	10-110 m
Other preferences	None
Migration Pattern	Non-migratory / resident

Habitat Information

Factors affecting distribution

Water flow and wave exposure
Pecten maximus tend to be most abundant just inside or just away from areas of strong currents (Mason, 1983). Gibson (1956) found that scallops living in sheltered areas grew faster than those on wave exposed beds and suggested that this was because the feeding apparatus become overwhelmed by particulate matter in the highly wave exposed areas. It is also possible that the delicate processes of larval settlement and byssal attachment would be disturbed in strong currents (Brand, 1991).

Substratum
The areas with highest abundance and the fastest growth rates of scallops are usually in areas with little mud (Brand, 1991). Gruffydd (1974) found that the maximum shell size of *Pecten maximus* from the north Irish Sea was significantly negatively correlated with increasing mud content in the sediment.

Aggregation and population subdivision
Adult scallops have a limited mobility and rely on the dispersal of larvae in terms of geographic distribution (Brand, 1991). The extent of this distribution will in turn be affected by factors including local hydrographic regimes and the survival of larvae. Consequently, all scallops have an aggregated distribution within their geographic range and the major fishing grounds are generally widely separated so much so that respective environmental conditions produce marked differences in population parameters (Brand, 1991).

However, in terms of genetic differences, two principle genetic population studies of *Pecten maximus* (Beaumont *et al.*, 1993; Wilding *et al.*, 1998) have failed to identify any evidence of sub-population structure (Beaumont , 2005). Wilding *et al.* (1999) found that the population of *Pecten maximus* from Mulroy Bay was more similar to *Pecten jacobaeus* than it was to other *Pecten maximus* populations, implying that this population is genetically distinct from others. This genetic isolation is thought to arise as a result of the enclosed nature of Mulroy Bay which probably means that the population is sustained through self-recruitment (Beaumont, 2005).

Life history

Adult characteristics

Reproductive type	Permanent (synchronous) hermaphrodite
Reproductive frequency	Annual protracted
Fecundity (number of eggs)	>1,000,000
Generation time	2-5 years
Age at maturity	Reach first maturity at 2 years and full maturity at 3-5 years.
Season	April - September
Life span	11-20 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

Lifespan

Mason (1983) reported a scallop with 18 growth rings although he stated that beyond the ninth or tenth ring, they are hard to distinguish and so attract some uncertainty in terms of age. Minchin (2003) states that the maximum age for *Pecten maximus* is about 22 years. In reality however, especially in heavily fished areas, the average age / size is reduced and those caught commercially rarely exceed 16 cm (Minchin, 2003). The rate of natural mortality is low at 10-15 % for adult *Pecten maximus* (Rees & Dare, 1993).

Spawning

The gametogenic cycle is highly variable and the timing of spawning may be influenced by both internal and external factors such as age and temperature respectively (Barber & Blake, 1991). Ansell *et al*. (1991) provide an excellent review of work done by several authors on populations of *Pecten maximus* in the Bay of Brest and the Bay of St Brieuc in France including work involving the transplantation of some individuals into different populations. They noted that differences in spawning cycles between populations reflect not only differences in their responses to local environmental variables but are also a consequence of genetic adaptation.

In general, mature scallops spawn over the summer months from April or May to September. Estimates of gamete emission range from 15 - 21 million oocytes per emission for a three year old (Le Pennec *et al*., 2003). A bi-modal spawning pattern has been reported by several authors in different areas. In Manx waters for instance, Mason (1983) found most of the adults spawned partially in the 'spring spawning' in April or May and then more fully in an 'autumn spawning' event in late August. He also found that the virgins (scallops that have not spawned previously) and juveniles (those between their first and second spawns) only had one major spawning in autumn. Spawning is followed by a period of recovery of the gonad before the next spawn. Gibson (1956) found a similar bi-modal spawning in Bere Island sound (Ireland) but here the spring spawn was reported to be the most significant of the two. In the same study (Gibson, 1956), the Bantry Bay area scallops matured up to six weeks earlier than the Connemara area further north. Fertilization is external and either sperm or eggs can be exuded first (Mason, 1983).

Dispersal

Dispersal potential in *Pecten maximus* is high given that the length of the pelagic larval stage exceeds one month. In addition, Beaumont & Barnes (1992) have observed 'byssus drifting' *in vitro* which would provide a possible mechanism for the secondary dispersal of post-larval stages (spat). Some spat were observed to detach from the byssus thread and the subsequent production of a long and fine drifting thread slowed the decent of the spat thereby increasing the potential for dispersal (Beaumont & Barnes, 1992). Thouzeau & Lehay (1988, cited in Le Pennec *et al.*, 2003) determined that *Pecten maximus* larvae could travel 10-40 km in 18 days due to tidal currents. However, Sinclair *et al.* (1985) hypothesized that using vertical migrations, larvae may be able to maintain their location within the confined of the scallop bed and that many aggregations are self-sustaining. Wilding *et al.* (1999) found that *Pecten maximus* from Mulroy Bay were genetically distinct to other populations. This genetic isolation is thought to arise as a result of the enclosed nature of Mulroy Bay which probably means that the population is sustained through self-recruitment (Beaumont, 2005).
See General (larval) information for details of larval development and settlement.

Sensitivity review

This MarLIN sensitivity assessment has been superseded by the MarESA approach to sensitivity assessment. MarLIN assessments used an approach that has now been modified to reflect the most recent conservation imperatives and terminology and are due to be updated by 2016/17.

Physical Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Substratum Loss	High	High	Moderate	Moderate

Removal of the substratum would result in loss of the entire population. Therefore an intolerance of high has been recorded. Recovery is potentially high (see additional information below).

	Intolerance	Recoverability	Sensitivity	Confidence
Smothering	Low	High	Low	Low

If *Pecten maximus* were smothered by a 5 cm layer of fine sediment, juveniles and adults could probably lift themselves clear of the new layer since thay are capable of jumping and swimming. Newly re-laid scallops are, however, more vulnerable to predators until recessed (Minchin & Buestel, 1983) although it is likely that the predators of the scallop such as starfish and crabs will be occupied in re-establishing their position themselves. Therefore an intolerance of low has been recorded. See additional information on recoverability below.

	Intolerance	Recoverability	Sensitivity	Confidence
Increase in suspended sediment	Low	High	Low	Moderate

Growth rates of adult *Pecten maximus* are adversely affected by increases in suspended sediments concentrations (Bricelj & Shumway, 1991) and excessive particle bombardment may threaten the viability of the feeding apparatus (Gibson, 1956), thereby potentially decreasing ingestion rates. The great scallop has the ability to swim and as such some individuals may be able to escape although this ability is primarily reserved for escape reactions given the high energy expenditure involved. However, the distances covered by swimming or jumping are very limited and newly re-laid scallops are more vulnerable to predators until recessed (Minchin & Buestel, 1983). Therefore an intolerance of low has been recorded and, at the benchmark level, recoverability is likely to be high.

	Intolerance	Recoverability	Sensitivity	Confidence
Decrease in suspended sediment	Tolerant	Not relevant	Not sensitive	Not relevant

Evidence suggests that scallops can compensate for short-term changes in the availability of food by adjusting the clearance rate of food particles (Bricelj & Shumway, 1991). In addition, *Pecten maximus* feed on a wide variety of food sources including phytoplankton, especially single celled algae, particulate organic matter (POM), bacteria and other micro-organisms (Fegley *et al.*, 1992; Reitan *et al.*, 2002). Consequently a short term decrease in the suspended sediment (see benchmark) is not likely to have an adverse effect on the scallops and a sensitivity of tolerant has been recorded.

	Intolerance	Recoverability	Sensitivity	Confidence
Dessication	Intermediate	Very high	Low	Moderate

Scallops are incapable of sustaining prolonged valve closure and are relatively intolerant of aerial exposure. Given their depth range *Pecten maximus* are unlikely to be subjected to aerial exposure unless, for example, they are taken to the surface during dredging and subsequently discarded (see section on selective extraction). Mikolajunas (1996) looked at the effect of aerial exposure on *Pecten maximus* and found that at first they respond to respiratory stress with rapid adductions (valve closures) of the shell but, due to the fact that they cannot

completely seal their valves, the soft tissue quickly becomes dehydrated and the animal eventually becomes fatigued (Mikolajunas, 1996). Following this the scallop will require a substantial recovery period following reimmersion although many will not recover if exposure has been prolonged. After just one hour of aerial exposure, as set in the benchmark, percentage mortality leveled off at about 60% after three weeks (Mikolajunas, 1996). Stressed scallops that are exhausted following periods of aerial exposure may not have the energy required to escape predation and other dangers. In addition they are less likely to recess and close their valves to avoid attack and the accumulation of waste and other stress related substances may attract predators (Mikolajunas, 1996). Jenkins & Brand (2001) state that exposure to the air for a little as twenty minutes could result in a significant reduction in the ability to swim.
In contrast, Brand & Roberts (1973) found that following short periods of aerial exposure most individuals responded well to reimmersion and showed a gradual and short term recovery on return to seawater. It is also notable that scallops remain alive far in excess of 24 hours in a refrigerator (K. Hiscock, pers. comm.)

Considering the benchmark for desiccation is set at one hour of continual aerial exposure for subtidal species it is likely that at least some of the population will be adversely affectedly and an intolerance of intermediate has been recorded. In light of the work by Brand & Roberts (1973), a recoverability of very high has been recorded.

Increase in emergence regime Not relevant Not relevant Not relevant Not relevant

Pecten maximus is not an intertidal species and emergence is not considered relevant.

Decrease in emergence regime Not relevant Not relevant Not relevant Not relevant

Pecten maximus is not an intertidal species and emergence is not considered relevant.

Increase in water flow rate Low Immediate Not sensitive Low

Pecten maximus lives embedded in recesses in the seabed usually with the upper valve flush with the sediment surface. This position can facilitate feeding by bringing the inhalant current near to the seabed therefore increasing the intake of detritus (Mason, 1983). It can also reduce the vulnerability of the scallop to dislodgment through increased water flow rate and wave action.
Growth rates of scallops are generally faster in areas of relatively strong currents and reduced growth rates can occur in areas of low current speeds due to food limitation. However, excessive particle bombardment, commonly associated with areas of high water flow rate, may reduce the effectiveness of the feeding apparatus and reduce ingestion rates (Gibson, 1956).
An increase of two categories in water flow rate (see benchmark) might repeatedly dislodge the scallop. This is unlikely to adversely affect the scallop and is likely that it will eventually re-settle although feeding may be disrupted which will subsequently reduce growth rates. Therefore, the viability of the population may be reduced, although feeding would most likely resume once conditions became suitable again. Therefore, an intolerance of low has been recorded.

Decrease in water flow rate Low Immediate Not sensitive Low

A reduction in water flow rate as set in the benchmark may reduce the availability of food particles but it is not likely that this reduction would adversely affect the growth and general condition of the scallop. Bricelj & Shumway (1991) suggested that scallops can compensate for short-term changes in the availability of food by adjusting the clearance rate of food particles. However, highly reduced water flow rates are often associated with increased siltation and growth rates of adult *Pecten maximus* have been found to be adversely affected by increases in suspended sediments concentrations (Bricelj & Shumway, 1991). Therefore, the viability of the population may be reduced however feeding would most likely resume once conditions became suitable again. Therefore an intolerance of low has been recorded.

Increase in temperature Intermediate High Low Moderate

Sexual maturation and spawning are governed by temperature which are obviously imperative for recruitment and contributing to the development of the population. Temperature is considered by many to be the primary trigger in spawning among Pectinidae and there is some evidence to suggest that there may be a critical range (Barber & Blake, 1991). In the Bay of Brest and the Bay of St Brieuc in France, for instance, the critical temperature range for spawning is thought to be between 15.5-16 °C (Paulet *et al*., 1988). Scallop spat reared at 17°C in the laboratory had the highest condition index, that is, the ratio of dry meat weight to dry shell weight (Laing, 2000). An increase in temperature similar to those of the benchmark may also stimulate phytoplankton production which would increase the amount of available food for both the adults and newly spawned larvae. No information was available on an upper threshold of temperature tolerance for adult *Pecten maximus* although Gruffydd & Beaumont (1972) observed high larval mortality above 20°C. Therefore a short term, acute increase in temperature of 5 °C may lead to the death of some individuals at the upper extreme of their temperature range, for example, West Africa, but it is not thought to affect the majority of *Pecten maximus* in the long term. Adults are likely to be more tolerant to changes in temperature than juveniles however and an intolerance of intermediate has been recorded accordingly.

Decrease in temperature High High Moderate Moderate

Sexual maturation and spawning are governed by temperature which are obviously imperative for recruitment and contributing to the development of the population. Temperature is considered by many to be the primary trigger in spawning among Pectinidae and there is some evidence to suggest that there may be a critical range (Barber & Blake, 1991). In the Bay of Brest and the Bay of St Brieuc in France, for instance, the critical temperature range for spawning is thought to be between 15.5-16 °C (Paulet *et al*, 1988). Decreases in temperature have been associated with decreases in feeding activity and spawning. In the laboratory, *Pecten maximus* has even been kept in water conditioned at 7-8°C to prevent spawning. Colder temperatures can depress development rate and, in extreme cases, lead to death. Evidence suggests that a reduction of temperature by 2°C is unlikely to adversely affect the population provided that other factors which act synergistically with temperature, for example salinity, remain the same.
However Crisp (1964b) reported mortalities approaching 100 % of *Pecten maximus* from several areas around the British Coast in the severe winter of 1962-1963 where the average sea temperature fell by approximately 4°C. Therefore a short term, acute reduction in temperature of 5°C may lead to the death of many individuals and therefore an intolerance of high has been recorded.

Increase in turbidity Tolerant Not relevant Not sensitive Not relevant

An increase in turbidity due to suspended particulate matter, plankton and dissolved substances will decrease light penetration through the water and subsequently decrease phytoplankton productivity. However *Pecten maximus* use a variety of food sources and this factor will probably have a limited effect. Therefore this species is probably tolerant.

Decrease in turbidity Tolerant Not relevant Not sensitive Not relevant

A decrease in turbidity may increase phytoplankton production which could potentially enhance the supply of food available to the scallops. However *Pecten maximus* use a variety of food sources and this factor will probably have a limited effect. Therefore this species is probably tolerant.

Increase in wave exposure	Intermediate	High	Low	Low

The water above seabeds at depths of up to 60 m can experience some oscillatory water movement in a strong swell or force 8 gale (Hiscock, 1983). Given their ability to recess it is unlikely that scallops at this depth would be dislodged by the water movement. However, scallops living in water depths of 10-20 m at the shallower extreme of their depth range may close their valves to reduce the scouring effect of the sand and gravel in high velocity water. In combination with the possible effect of sustained displacement, feeding is likely to be reduced and possibly prevented which will ultimately reduce growth rates. The action of waves has been considered a main source of mortality of *Pecten maximus* in some areas in the Bay of St Brieuc (Thouzeau & Lehay, 1988, cited in Orensanz *et al*., 1991) and, therefore, an intolerance of intermediate has been recorded.

Decrease in wave exposure	Tolerant	Not relevant	Not sensitive	

A decrease in wave exposure similar to that of the benchmark is unlikely to have an adverse effect on the population therefore tolerant has been recorded.

Noise	Tolerant	Not relevant	Not sensitive	Low

This species probably has very limited ability for noise detection and therefore is thought to be tolerant.

Visual Presence	Low	Immediate	Not sensitive	Moderate

Scallops have eyes around the margin of the shell (see adult general biology) and will swim, orient themselves or close their shell in response to shadows or movement (Wilkens, 1991). Buddenbrock & M&#246ller-Racke (1953, cited in Mason, 1983) found that *Pecten maximus*' reaction to moving objects depended on the velocity of the moving object and fast moving objects could result in the closure of the valves. Scallops living in shallower water between 10-40 m may therefore be affected by the visual presence of divers and boats for example, however this is unlikely to cause an adverse effect. In addition. sight reaction decreases in sensitivity to repetitive stimulation (Wilkens, 1991) and a recoverability of immediate has been recorded.

Abrasion & physical disturbance	Low	High	Low	Moderate

Scallop dredging can cause damage to the scallop shells and in particular to the growing edge. Ansell *et al*., (1991) stated that up to 19 % of the scallops left behind by a dredge are affected to some extent. Effects might include shell damage, burial, increased stress and feeding difficulties associated with the increased suspended sediment produced by the action of the dredge. Individuals with damaged shells are more prone to predation. In addition, the energy budget would be altered so that energy previously reserved for spawning would be allocated to new shell growth and therefore reduce the viability of the population. However, Jenkins *et al*,, (2001) reported that, during dredging, more than 90 % of *Pecten maximus* that came into contact with a dredge (including those landed, discarded and left behind by the dredge) were in good condition overall and showed little or no shell damage. It is possible that some smaller individuals may be crushed and killed by a scallop dredge although for the majority of the population it is unlikely that it will have an adverse effect so an intolerance of low has been recorded.

Displacement	Tolerant	Not relevant	Not sensitive	Not relevant

Pecten maximus is capable of righting itself if disturbed by repeated ejection of water jets directed at the sediment. Individuals can also perform swimming movements and move around randomly until a suitable substrate for recessing is located (Ansell *et al.*, 1991). The distances covered by scallop movement are very limited and newly re-laid scallops are more vulnerable to predators until recessed (Minchin & Buestel, 1983) however it is not thought that this factor will have a particularly adverse effect on the scallops and tolerant has been recorded.

Chemical Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Synthetic compound contamination	Intermediate	High	Low	Moderate

Pecten maximus naturally accumulates metal-phosphates in concretions in the renal organs (George *et al.*, 1980). TBT-based antifouling paint was shown to be detrimental to growth and survival of juvenile scallops (Paul & Davies, 1986) and there is some recent evidence that recruitment to inshore scallop beds may have been affected by TBT used in anti-fouling paints (Minchin *et al.*, 1987). Declining populations of *P. maximus* in Mulroy Bay, Northern Ireland correspond well with the introduction of organotin net dips which had been used in the local salmon farms (Minchin *et al.*, 1987). The first year after the use of the dips had ceased saw a good settlement of scallops compared to, for example, 1984 and 1985 when no settlement was observed. No information concerning the effects of other synthetic compounds on *Pecten maximus* was found but it is likely that at least some of the population may be killed and therefore an intolerance of intermediate has been recorded.

Heavy metal contamination	Intermediate	High	Low	Low

Scallops concentrate metals in their tissues with an efficiency greater than that of other bivalves (Gould & Fowler, 1991). When *Pecten maximus* is grown in close proximity to copper-oxide based antifouling paint, high levels of copper may be accumulated in the tissues although much of the copper is gradually lost from the scallop even when still in the presence of the copper oxide (Davies & Paul, 1986). Further loss of copper was seen after the scallops had been transferred to untreated enclosures (Davies & Paul, 1986). Further experiments looked at growing adult and juvenile *Pecten maximus* in enclosures treated with various anti-fouling compounds and found that trays treated with copper-nickel compounds induced high mortality in juveniles and prevented growth in adults (Paul & Davies, 1986). In contrast, the copper-oxide based paint actually increased spat growth to some extent and had no effect on the adult specimens. It is likely that different heavy metals and their compounds will have various effects on adult *Pecten maximus* although the majority of research on this subject focuses on the partitioning of metals within the scallop tissues and little information on the effects was found. Nevertheless, the mortality of juveniles indicated by the work by Paul & Davies (1986) has led to an intolerance of intermediate being reported.

Hydrocarbon contamination	Low	High	Low	Low

The effects of oil spills on scallops are considered to be relatively short lived (Gould & Fowler, 1991) and diving investigations in Bantry Bay following the release of 30,000 tons of Arabian light crude oil from a tanker explosion in 1979 found that, although there was some minor contamination, the oil did not affect spatfalls in 1979 or 1980 (Grainger *et al.*, 1984). The amount of sunken oil was limited and *Pecten maximus* showed no abnormal behaviour or mortality as a result of the oil contamination. However, a taste panel test revealed that scallops living in the vicinity of the sunken oil were still tainted two years after the spillage. Oil pollution may therefore affect the viability of scallop fisheries resulting from the reduction in meat quality although it is unlikely to adversely affect the viability of the population *per se*. Endosulfan, a chlorinated hydrocarbon, was found to affect the oxygen consumption in *Pecten maximus*. Roberts (1975) found that if the concentration of Endosulfan in the water exceeded 1mg /day, the valves of *Pecten maximus* remained closed for increasingly longer periods of time and oxygen consumption fell. The exact consequences of a sustained lack of oxygen for scallops are not known but it is probable that the animal will experience respiratory stress. Scallops at first respond to respiratory stress with rapid adductions of the shell and the animal eventually becomes fatigued (Mikolajunas, 1996). Stressed scallops may not have the energy required to escape predation and other dangers and the viability of the population will therefore be reduced. Therefore, an intolerance of low has been recorded.

Radionuclide contamination		Not relevant		Not relevant

No information was found on the effects of radionuclide contamination on *Pecten maximus* but field collections of other scallop species have shown that radionuclides are accumulated but few adverse effects on growth and survival were seen (Gould & Fowler, 1991). For example, Baptist *et al.* (1976, cited in Gould & Fowler, 1991) exposed juvenile Bay scallops *Argopecten irradians* to a cumulative radiation dose of ca 70 Krads over three months but did not observe any deleterious effects on either the growth or survival of the scallops.

Changes in nutrient levels	Intermediate	High	Low	Moderate

The effects of an increase in the amount of nutrients will depend on the form of enrichment and on the primary production it stimulates. A study in the Bay of Brest (Chauvaud *et al.*, 1998) found that, regardless of the specific phytoplankton composition, high concentrations of chlorophyll-a reduced the daily growth rate of juvenile *Pecten maximus*. High concentrations of chlorophyll-a following diatom blooms have also been implicated in causing negative effects on the ingestion and respiration of *Pecten maximus* juveniles either by clogging their gills or by depleting the oxygen at the water-sediment interface during the degradation of organic matter (Lorrain *et al.*, 2000). The high levels of nutrient enrichment as set in the benchmark may lead to (depending on other environmental conditions) eutrophication and the possibility of subsequent increases in turbidity and suspended material and decreases in the amount of available oxygen. A decrease in *Pecten maximus* growth rate and reproduction has been observed in the presence of certain toxic algal blooms (Chauvaud *et al.*, 1998). For instance *Gymnodinium* cf. *nagasakiense* can lead to the death of post-larval and juvenile *Pecten maximus* in the wild (Erard-Le Denn *et al.*, 1990, cited in Chauvaud *et al.*, 1998) and in 1995, three major blooms of *Gymnodinium* cf. *nagasakiense* in the Bay of Brest inhibited the settlement of spat although a rapid return to normal shell growth rates was reported once the numbers of *Gymnodinium* sp. had decreased (Chauvaud *et al.*, 1998).
In contrast, Reitan *et al.* (2002) experimentally enhanced the nutrient supply in a landlocked bay in Norway and found that the resulting increase in the phytoplankton biomass had a significant positive effect on growth rates of *Pecten maximus* .
It is likely that some of the population will be adversely affected by such a large increase in nutrient levels and an intolerance of intermediate has been recorded. However, it is likely that the recovery period will be relatively rapid.

Increase in salinity	Not relevant	Not relevant	Not relevant	Not relevant

Pecten maximus invariably live in areas associated with full salinity water and as such, an increase in salinity is not thought to be relevant.

Decrease in salinity	Intermediate	Moderate	Moderate	Moderate

The inability of *Pecten maximus* to close its valves makes them highly vulnerable to low salinity stress (Bricelj & Shumway, 1991). Christophersen & Strand (2003) found that in the laboratory, the shells of spat held in water with a low salinity (20 ppt) became thin and easily damaged which ultimately led to a negative shell growth rate. They found that, in general, behaviour was also affected and the scallops made fewer foot movements and retracted the mantle from the shell margin. This could presumably decrease the effectiveness of the feeding apparatus. Several authors have reported the synergistic effects of salinity and temperature on various aspects of *Pecten maximus* physiology. For instance, Laing (2002) found that between 13-21 °C the growth rate was significantly lower at 26 psu than at 28-30 psu and Christophersen & Strand (2003) found that at 25 ppt and 30 ppt, higher growth rates were seen at 18 °C than at 15 °C. Laing (2002) also found that the food cell clearance rate decreased with salinity. However, the reductions in growth rate were temporary and growth rates returned to that of those spat held in ambient salinities within 10 days of exposure (Laing, 2002). For short term acute changes (see benchmark), the viability of the population is likely to be reduced however recovery will be fairly rapid. Long term chronic changes are likely to have an adverse affect on the population affecting both juvenile and adult scallops. The juveniles are likely to suffer to the extent that they may not survive into adulthood by becoming more vulnerable to, for example, predation and general wear and tear. This could have severe implications for recruitment to the population and it is likely that the population will take several years to recover therefore an intolerance of intermediate has been recorded.

Changes in oxygenation	Low	High	Very Low	Low

Scallops, as sublittoral, epifaunal bivalves which are incapable of sustaining prolonged valve closure, are relatively intolerant of anoxia (Bricelj & Shumway, 1991). Brand & Roberts (1973) found that scallops transferred to de-oxygenated water (13 mm Hg) for three hours experienced rapid bradychardia (reduced heart rate). However, the length of exposure time set in the benchmark is one week which is significantly longer than the length of Brand & Roberts (1973) experimental work. It is likely that scallops will experience some respiratory stress at the level set in the benchmark. It is possible that feeding will be reduced and the animal may become lethargic thus making it more susceptible to predation due to a weakened escape response. This will reduce the viability of the population and therefore a sensitivity of low has been recorded. However, Brand & Roberts (1973) found that the scallops that had been exposed to the de-oxygenated water recovered well upon return to well-oxygenated water (135 mm Hg) therefore a recoverability of high has been recorded.

Biological Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Introduction of microbial pathogens/parasites				Not relevant

Minchin (2003) lists some examples of parasites and diseases affecting scallops including polychaete, copepod and gastropod infestations.*Pseudoklossia pectinis*, a protistan parasite, causes hypertrophy in the kidney cells of *Pecten maximus* from Roscoff, France although the overall damage to the kidney appears to be light (L&#233ger & Duboscq, 1917, cited in Kinne, 1983).
A rickettsial disease has been known to cause mortality in French stocks (Le Gall *et al.*, 1988; Ansell *et al.*, 1991).
Mortensen *et al.* (2000) reported the loss of over one million spat, approximately one third of Norway's scallop production, due to the heavy infestation of the scallops with *Polydora* species (worms that bore into calcium carbonate shells). Overall, the information on microbial pathogens affecting *Pecten maximus* is comparatively little in relation to other commercial bivalves.

Introduction of non-native species Not relevant

The leathery tunicate *Styela clava* is occasionally found attached to the upper valve of *Pecten maximus* but is unlikely to cause displacement (K. Hiscock, pers. comm.).

Extraction of this species Intermediate Moderate Moderate Low

Various reasons including overexploitation have resulted in declines in wild populations of *Pecten maximus* and due to the highly variability nature of recruitment in this species, much emphasis is now being placed on its aquaculture. In Shetland, for instance, scallop landings in 1969 neared 600 t but then fell to 96 t only four years later (Mason, 1983). By 1977 the catches had increased again but only to 224 t. Many scallops are now artificially cultured in farms and management measures have been enforced in many areas. Due to the nature of scallop dredging the extraction of this species is likely to adversely affect the species by removing a proportion of the population, although estimates for the efficiency of the dredge are usually below 20% (Mason, 1983).

There are two main scenarios concerning the extraction of this species: the effects resulting from scallop dredges on those scallops that are not caught and also the effects on the population when scallops are caught.

For those that manage to escape being caught there will be a considerable amount of stress involved if the scallop has come in close contact with the dredge. Frequently, the scallop may be exhausted from trying to escape capture by the dredge and may therefore be more vulnerable to predation. Jenkins & Brand (2001) reported that dredging caused a significant increase in the response time of scallops to predators.

For those scallops that are caught but subsequently discarded due to their size, namely scallops below the Minimum Landing Size (MLS), aerial exposure will also cause a certain amount of stress, especially if the period of exposure is prolonged (see section on desiccation). Jenkins & Brand (2001) state that exposure to the air for even a twenty minute period cause a significant reduction in the ability to swim.

As far as the landed scallops are concerned, Brand