China limpet (*Patella ulyssiponensis*)

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

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2004-08-10

A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

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This review can be cited as:
Neal, K.J. & Skewes, M. 2004. *Patella ulyssiponensis* China limpet. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinsp.1570.2

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Shell of the china limpet on rocky shore
Photographer: David Fenwick
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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	Ken Neal & Marie Skewes	**Refereed by**	This information is not refereed.
Authority	Gmelin, 1791		
Other common names	-	**Synonyms**	*Patella aspera* Röding, 1798

Summary

Description

Shell forming a low cone with ridges on the outer surface that project noticeably around the edges of the shell. *Patella ulyssiponensis* reaches up to 6 cm in length and the apex is noticeably anterior to the centre. The outer surface of the shell is a whitish-grey while the inner surface is a porcellanous white, with a yellow or orange hint towards the apex. The sole of the foot is orange or yellow, and the mantle is edged with translucent white tentacles.

Recorded distribution in Britain and Ireland

The china limpet is found around most of the coast of the British Isles, reaching its northern limit in the Shetland Isles. Absent or rare on south-east shores of England from the Humber Estuary to the Isle of Wight.

Global distribution

Patella ulyssiponensis is a southern (Lusitanian) species extending south to the Mediterranean.

Habitat

Common on exposed rocky shores, avoiding extreme shelter and low salinities. Present on the lower shore and, rarely, in the shallow sublittoral. Also occurring in shallow rock pools on the middle shore and on overhanging rocks and the sides of gullies.

Depth range

Intertidal

Identifying features

- Radiating ridges on the outer surface, often with tubercles where crossed by growth lines and projecting noticeably around the edges of the shell.
- Characteristic pattern of alternating single and triple ridges.
- Anterior end of shell distinctly narrower than posterior.
- The sole of the foot is orange or yellow and the mantle is edged with translucent white tentacles.

Additional information

Patella ulyssiponensis was formerly known as *Patella aspera*.

Listed by

Further information sources

Search on:

NBN WoRMS

Biology review

Taxonomy

Phylum	Mollusca	Snails, slugs, mussels, cockles, clams & squid
Class	Gastropoda	Snails, slugs & sea butterflies
Family	Patellidae	
Genus	Patella	
Authority	Gmelin, 1791	
Recent Synonyms	Patella aspera Röding, 1798	

Biology

Typical abundance	High density
Male size range	0.25 - 58mm
Male size at maturity	20mm
Female size range	18mm
Female size at maturity	
Growth form	
Growth rate	5 - 7mm/year
Body flexibility	None (less than 10 degrees)
Mobility	
Characteristic feeding method	
Diet/food source	
Typically feeds on	Epilithic algae and biofilms.
Sociability	
Environmental position	Epibenthic
Dependency	No text entered.
Supports	See additional information
Is the species harmful?	No

Biology information

On rocky shores of wave exposure grade 1 (Ballantine scale: Ballantine, 1964), *Patella ulyssiponensis* occurs at densities of 1000 m▯ but individuals are small (Thompson, 1979). On less wave exposed shores density is lower but individuals are larger.

Patella ulyssiponensis is parasitised by *Cercaria patellae*, a trematode platyhelminth, which have infection levels of 5-10% in adults and can cause damage of the digestive gland. Gymnophallid metacercariae infect between the mantle and the shell and have an infection level of approximately 5%. The gut of *Patella ulyssiponensis* is sometimes infected by larval cyclophyllidean tapeworms (Kinne, 1980).

Habitat preferences

Physiographic preferences	Open coast

Biological zone preferences	Sublittoral fringe, Upper infralittoral
Substratum / habitat preferences	Bedrock
Tidal strength preferences	Strong 3 to 6 knots (1.5-3 m/sec.), Very Strong > 6 knots (>3 m/sec.)
Wave exposure preferences	Exposed, Extremely exposed, Very exposed
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Depth range	Intertidal
Other preferences	No text entered
Migration Pattern	Non-migratory / resident

Habitat Information

In wave exposed situations, *Patella ulyssiponensis* is the commonest limpet on the lower shore.

Life history

Adult characteristics

Reproductive type	Protandrous hermaphrodite
Reproductive frequency	Annual episodic
Fecundity (number of eggs)	No information
Generation time	2-5 years
Age at maturity	3 years
Season	August - October
Life span	11-20 years

Larval characteristics

Larval/propagule type	-
Larval/juvenile development	Planktotrophic
Duration of larval stage	2-10 days
Larval dispersal potential	Greater than 10 km
Larval settlement period	Insufficient information

Life history information

Maturation of gonads begins in May/June and all mature individuals have ripe gonads by mid-August. Spawning occurs in October and is believed to be triggered by strong gales (Thompson, 1979). The sex ratio of this species varies with size of individual. For example, at 20 mm shell length, all mature individuals are male, while from 20 mm to full size the number of females increases until at 55 mm around 70% of the mature individuals are female (Thompson, 1979).

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

The species is epifaunal so loss of the substratum would also result in loss of the population. Individuals unattached to the substratum are very vulnerable to desiccation and to predation by birds and crabs. An intolerance of high has therefore been recorded. For recoverability, see additional information below.

	Intolerance	Recoverability	Sensitivity	Confidence
Smothering	High	High	Moderate	High

A related limpet, *Patella granularis*, was found to survive no more than 3 days when smothered with sand. This effect was thought to be due to hypoxia caused by the sand preventing a normal current of water passing over the gills (Marshall & McQuaid, 1989). Also, inundation with sand is likely to affect locomotion and grazing and cause the limpet to starve (Professor Steve Hawkins, pers. comm.). Therefore an intolerance of high has been recorded. For recoverability, see additional information below.

	Intolerance	Recoverability	Sensitivity	Confidence
Increase in suspended sediment	Low	Very high	Very Low	Very low

Since *Patella ulyssiponensis* is a grazer on rocky shores, an increase in suspended sediment is unlikely to reduce its ability to find food. Predation rates are unlikely to be affected since its principal underwater predators (crabs and starfish) use senses other than sight to locate prey and birds (such as oystercatchers) prey on limpets when they are exposed by the tide. An increase in suspended sediment may clog the gills of limpets and lead to difficulties in extracting oxygen from the water. Intolerance is assessed as low.

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

Patella ulyssiponensis is not reliant on suspended sediment for food or shelter so a decrease is unlikely to affect this species. Therefore tolerant has been recorded.

	Intolerance	Recoverability	Sensitivity	Confidence
Dessication	High	High	Moderate	High

Patella ulyssiponensis suffers 100% mortality at 40% water loss. In comparison, *Patella vulgata* suffers at most 30% mortality at the same water loss (Davies, 1969). Therefore, at the benchmark level, an intolerance of high has been recorded.

	Intolerance	Recoverability	Sensitivity	Confidence
Increase in emergence regime	Intermediate	High	Low	Low

Patella ulyssiponensis is found on the lower shore and in rock pools in the mid-shore. If emergence increased adults may migrate down the shore although it is also possible that some individuals would stick to their home scars and die. Therefore an intolerance of intermediate has been recorded reflecting some mortality.

	Intolerance	Recoverability	Sensitivity	Confidence
Decrease in emergence regime	Tolerant	Immediate	Not sensitive	Low

Some *Patella ulyssiponensis* occur subtidally, therefore an decrease in emergence would probably not affect this species. Therefore tolerant has been recorded.

Increase in water flow rate Tolerant Not relevant Not sensitive Moderate

Limpets are extremely tenacious and tests on one species, *Lottia pelta*, showed that they will only begin to be dislodged by water currents in excess of 13 m/s (25 knots) while stationary and 8 m/s (16 knots) while moving. To remove all the limpets from a surface would take current speeds in excess of 20 m/s (39 knots) (Denny, 1989). Tidal currents in the waters of Britain and Ireland do not exceed 10 knots in surface velocity. Therefore tolerant has been recorded.

Decrease in water flow rate Tolerant Not relevant Not sensitive

If the reduction in water flow rate was concomitant with a reduction in wave exposure then *Patella ulyssiponensis* may become less abundant or disappear entirely. Under any other circumstances, a decrease in water flow rate is unlikely to affect this species. Therefore tolerant has been recorded.

Increase in temperature Tolerant Not relevant Not sensitive Low

Grazing activity in limpets is closely correlated with temperature: the warmer it is, the more time limpets spend grazing (Jenkins *et al.*, 2001). A slight warming is likely to be beneficial to individual and population growth. *Patella ulyssiponensis* is less tolerant than *Patella vulgata* to changes in temperature. However, since it occurs in the sublittoral fringe and in rock pools in the mid-shore, changes in temperature at the benchmark level are likely to be buffered. Therefore tolerant has been recorded for an increase in temperature.

Decrease in temperature Intermediate High Low Low

A related species, *Patella vulgata*, loses adhesion at very low temperatures and become very vulnerable to crab and bird predation (see review of *Patella vulgata*). The water in a rock pool will buffer sudden and drastic changes in air temperature until the tide returns with warmer water and thus protect any organisms within the pools. In the very cold winter of 1962-63 *Patella ulyssiponensis* suffered less mortality than other limpets because it was protected by the warmer seawater because it was not exposed to the cold air temperatures for very long each day. An intolerance of intermediate has been recorded for a decrease temperature because extreme cold in winter is likely to kill a proportion of the population.

Increase in turbidity Tolerant Not relevant Not sensitive Moderate

Increasing turbidity is unlikely to directly affect *Patella ulyssiponensis* but may reduce the amount of light reaching the epilithic algae at high tide. This will reduce the productivity of the epilithic algae and may affect the growth and reproductive output of the organisms which feed upon it (Langston *et al.*, 2003). Therefore tolerant has been recorded.

Decrease in turbidity Tolerant* Not relevant Not sensitive* Low

A decrease in turbidity is likely to benefit to all rocky shore grazers by increasing the amount of light reaching the epilithic algae and increasing productivity which will probably increase the productivity of the grazers. Therefore tolerant* has been recorded.

Increase in wave exposure Tolerant Not relevant Not sensitive Moderate

Limpets are extremely tenacious and *Patella ulyssiponensis* occurs at the highest densities on the most wave exposed shores: up to 1000 m^{-2} on extremely exposed shores (Thompson, 1979). Therefore an increase in exposure is unlikely to affect this species.

Decrease in wave exposure Intermediate High Low Moderate

Patella ulyssiponensis prefers wave exposed shores with little fucoid cover and is intolerant to a reduction in wave exposure (Evans, 1953). However the effect of a decrease in wave exposure on a population of *Patella ulyssiponensis* depends on the wave exposure before the decrease. The benchmark is a 2 rank change in the wave exposure of the shore. Therefore, if the *Patella ulyssiponensis* population started at extremely exposed and ended up at exposed, little change in the population would occur since fucoids only start to appear on moderately exposed/sheltered shores (Little & Kitching, 1996) and *Patella ulyssiponensis* is tolerant to sparse fucoid cover (Evans, 1953). However, if the population started on an exposed shore and ended up on a sheltered shore, the *Patella ulyssiponensis* are likely to become locally extinct in that area until the returns to its previous exposure grade. An intermediate intolerance of a reduction in wave exposure has therefore been recorded to take into account the worst case scenario described above.

Noise	Tolerant	High	Not sensitive	Low

Although limpets are not likely to be affected by atmospheric noise levels, vibrations near to the animal will cause the shell muscles to contract vigorously, clamping the limpet to the rock (Fretter & Graham, 1994), and potentially interfere with respiration and foraging in pools. This is unlikely to seriously affect *Patella ulyssiponensis* at the benchmark level and therefore tolerant has been recorded.

Visual Presence	Tolerant	Very high	Not sensitive	Low

Patella ulyssiponensis has eyes and is sensitive to visual presence. The limpet may clamp down onto its home scar in response to, for example, the presence of humans on the shore. However, this reaction is short lived and is unlikely to adversely affect the viability of the species. Therefore tolerant has been recorded.

Abrasion & physical disturbance	Intermediate	High	Low	Very low

The adult has a tough shell that offers protection from abrading factors and any near vibration causes the shell muscles to contract vigorously, clamping the animal to the rock. A short, sharp knock may dislodge an individual leaving it vulnerable to predation and limpets may be crushed by wave driven debris or by seagoing vessels grounding on the shore. However, small individuals tend to occupy depressions, crevices, or pools that would provide protection from trampling or the scraping that would occur when a vessel goes ashore. Therefore, an intolerance of intermediate has been recorded.

Displacement	Intermediate	High	Low	Very low

Limpets are intolerant of being knocked off the rock by trampling on the shore and, if the foot is damaged, do not re-attach easily (Professor Steve Hawkins, pers. comm.). Displaced individuals with the foot exposed to the air are likely to become prone to predation and desiccation and may die. If individuals remain foot down on rock after displacement and are not damaged they may be able to become reattached. However, individuals removed several feet from their scars do not appear to make their way home again (Fretter & Graham, 1996) and so may be more vulnerable to desiccation without the tight fit to their 'home scar'. Therefore, an intolerance of intermediate has been recorded.

Chemical Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Synthetic compound contamination	High	High	Moderate	High

Limpets are extremely intolerant of fresh oil and any solvent based dispersants used in oil spill clean-up. During the clean-up response to the *Torrey Canyon* oil spill, nearly all the limpets were killed in areas close to dispersant spraying (Southward & Southward, 1978). Viscous oil

will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone, or diluted in sea water, would creep in much more readily and be liable to kill the limpet (Smith, 1968). A concentration of 5 ppm of chemical dispersant killed half the limpets tested in 24 hours (Southward & Southward, 1978; Hawkins & Southward, 1992).
Sub-lethal effects on limpets are also relevant. The limpets may be narcotized by the fresh oil which may render them incapable of clamping down on their home scar. Consequently they may be more vulnerable to predation since they would be easier to prize off the rocks. In addition, they may be more susceptible to dislodgment by, for example, wave exposure and wave driven debris. When limpets move around on the rock they leave a mucous trail which enables them to retreat back to their home scar. If contact with this mucous trail is broken it is unlikely that the limpet will successfully find its way back to its home scar. This will also leave the limpet more prone to predation.

Acidified sea-water affects the motility of *Patella vulgata*. At a pH of 5.5, motility was reduced whilst submerged but individuals recovered when returned to normal sea-water. At a pH of 2.5, total inhibition of movement occurred and when returned to normal sea-water half had died (Bonner *et al*., 1993). Reduced motility reduces time for foraging and may result in decreased survival of individuals. Acidified seawater can also change the shell composition which will lead to a decrease in its protective nature and hence survival (Bonner *et al*., 1993). Short periods (48 hours) are unlikely to have much effect on a population but long periods (1 year) may cause reduced grazing and an increase in algal growth. However, sea-water is unlikely to reach pH 2.5 therefore intolerance to slight changes in pH will be low. Gastropod molluscs are known to be intolerant of endocrine disruption from synthetic chemicals such as tri-butyl tin (Cole *et al*., 1999). However no information on the specific effects of tri-butyl tin on *Patella vulgata* was found. Hoare & Hiscock (1974) reported that in Amlwch Bay *Patella vulgata* was excluded from sites within 100-150 m of the discharge of acidified, halogenated effluent. Therefore an intolerance of high has been recorded.

Heavy metal contamination	Low	High	Low	High

Limpets are regarded as good bioindicators of heavy metal pollution because they tend to accumulate metals at levels proportional to their environment (Catsiki *et al*., 1991). Limpets isolate and detoxify heavy metals by producing metallothioneins in response to heavy metal pollution (Bebianno *et al*., 2003). Metallothioneins are low molecular weight proteins that bind metal cations, their production allows an organism to tolerate heavy metal pollution but presumably have a metabolic cost that increases with greater heavy metal exposure. Limpets also adjust their physiology and behaviour in response to heavy metal exposure. Exposure of *Patella ulyssiponensis* to 0.5 ppm of copper caused the limpets' hearts to stop beating (probably to prevent metal absorbed through the gills travelling around the body) but heart activity returned to normal once the limpets were returned to clean seawater (De Pirro *et a*l., 2001). Exposure to solutions of copper and zinc were found to suppress activity in *Patella ulyssiponensis* by causing them to clamp their shell onto the substratum and thus isolate them from the environment (Davies, 1992). In this way, *Patella ulyssiponensis* can tolerate short pulses of heavy metal input but longer term exposure will have energetic consequences for the limpets. In summary, limpets will be stressed by exposure to heavy metals but widespread mortality is unlikely and therefore their intolerance is recorded as low.

Hydrocarbon contamination	High	High	Moderate	High

The resistance of *Patella ulyssiponensis* to direct oiling is poor and causes high mortalities. Weathered oil that has been deposited on the bedrock of the shore gets scraped off during grazing by limpets and ends up in their digestive system. This does not seem to affect them, presumably because there is little of the lighter, more toxic fractions of the oil left (Southward & Southward, 1978).
Petpiroon & Dicks (1982) studied the long term effects an oil refinery discharge had on the surrounding shore communities in Littlewick Bay, Milford Haven. By combining their own field work with earlier studies in the same area it was evident that numbers of *Patella* species had fallen considerably at the two sample sites nearest the discharge pipe (the pipe being approximately 100 m away) since the 1960s. Individuals that were found within the vicinity of the pipe were comparatively much larger. In addition, no juveniles were found within about 45 m of the outfall suggesting that larval recruitment was affected either through the direct mortality of the larvae or by inhibiting larval settlement on the substratum surrounding the pipe. This would also explain the lack of younger, smaller individuals nearest the pipe. The maximum oil content in the effluent gradually decreased from 50 ppm at the start of the work to 25 ppm at the end of the study. Fieldwork in 1981 (the end of the study) found that some juveniles had settled at the two sampling stations nearest the pipe. However the reduction in oil content was not thought to have corresponded with any reduction in the biological effects of the effluent. Petpiroon & Dicks (1982) suggested that at least part of the observed effects resulted from the effluent effects on the larval stages as opposed to the adults directly. In addition, the low salinity of the effluent and the sheltered nature of the receiving waters had meant that the effluent floated after discharge and as a result made contact with all levels of the shore during each tide.

Overall, due to the lethal effect that direct oiling has on the limpets an intolerance of high has been recorded.

Radionuclide contamination		Not relevant		Not relevant

No information found.

Changes in nutrient levels	Tolerant*	Not relevant	Not sensitive*	High

Limpets near sewage outfalls have a higher growth rate than those further away but mortality is higher. However the source of mortality was unknown (Tablado *et al*., 1994). In another study, there was a massive mortality of limpets 2-3 weeks after a nearby sewage outfall was shut off permanently: the nutrient enrichment from the outfall had led to a dense growth of sea lettuce, *Ulva lactuca*, which supported a very large population of limpets. Once the enrichment ceased, the *Ulva lactuca* could not recover from grazing damage as quickly as before and was eventually completely removed from the area around the outfall. With their food source eradicated, a large proportion of the limpets starved (Rogers, 2003). Limpets often benefit from nutrient enrichment (Rogers, 2003 and Tablado *et al*., 1994) and can survive extended periods the anoxia (Santini *et al*., 2001) that excludes many organisms from areas of organic enrichment. A drop in nutrient levels is more difficult to assess. Mass mortalities of limpets have been described when artificial enrichment is removed but this probably represents a return to an environmental equilibrium in place before the enrichment occurred. It can only be assumed that if nutrient decreased in an area with no previous enrichment that the limpets' growth would be slowed and that reproductive output would also be reduced. As nutrient further decreased, the population would presumably thin out as some individuals starved. Based upon the evidence of increasing population size with organic enrichment, an intolerance of tolerant* has been recorded.

Increase in salinity	Low	High	Low	High

In laboratory experiments, *Patella ulyssiponensis* survived 43psu for 24 minutes and was only killed when placed in 63 psu for 24 minutes. The metabolic rate of the limpets increased in increasing salinity and this was thought either to be a result of increased locomotion (an escape response) or maintenance of cell volume (De Pirro *et al.* 1999). Gastropods are osmoconformers, meaning that the salinity of their body fluids is equal to that of their surroundings but in high salinities, water will leave their cells so metabolism has to increase to pump water back into cells to maintain their volume. Because of the various ways *Patella ulyssiponensis* can cope with an increase in salinity, an intolerance of low has been recorded.

Decrease in salinity	High	High	Moderate	High

Patella ulyssiponensis does not penetrate into estuaries although its tolerance of short periods of low salinities is high (Evans, 1953). Lack of penetration into estuaries may be because of increased shelter. Rainfall can significantly lower the salinity of the rock pools it inhabits. *Patella ulyssiponensis* survived 24 minute exposures at 23 psu without apparent physiological effect but there was 100% mortality when exposed to 3 psu for more than 20 minutes. The limpets' response to low salinity was the same as when exposed to high salinity i.e. metabolic rate increased (De Pirro *et al.*, 1999). It seems that *Patella ulyssiponensis* occurs only in full and variable salinity. It is probably highly intolerant of decreases in salinity at the benchmark level.

Changes in oxygenation	Low	High	Low	Moderate

It was assumed for some time that limpets experience anoxia with emergence during every tide, due to the limpets clamping down their shells to avoid desiccation. However, it has been found that limpets will raise their shells to allow transfer of air but at the cost of water loss. Their gills are inefficient at absorbing oxygen from air and limpets are expected to be subject to moderate anaerobic conditions during low tide. In water, limpets can survive at least 18 hours in completely anoxic water by respiring anaerobically (the species studied was *Patella caerula*) (Santini *et al.*, 2001). Given that limpets do well in areas of organic enrichment (Rogers, 2003; Tablado *et al.* 1994) which are often hypoxic due to bacterial respiration. Overall, an intolerance of low has been recorded.

Biological Pressures

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

No information found.

Introduction of non-native species		Not relevant		Moderate

Patella ulyssiponensis is not known to compete with any non-native species.

Extraction of this species	Intermediate	High	Low	High

The flesh of *Patella ulyssiponensis* is highly prized in the Azores and Azorean communities in the USA and, in 1985, was the sixth most important fishery in the Azores (Martins *et al.*, 1987; Corte-Real *et al.*, 2000). Azorean stocks of *Patella ulyssiponensis* began to decline in the 1970s when snorkel diving became the main means of collection. The fishery was stable as long as recruitment remained high and only individuals 40 mm long were taken so that the limpets matured and bred before extraction. On some of the central islands of the Azores, individuals as small as 20 mm were being taken and the population was in decline because recruitment from outlying populations was low (Martins *et al*., 1987). A ban on limpet extraction in these areas has probably saved these populations of *Patella ulyssiponensis*. Therefore *Patella ulyssiponensis* is probably sensitive to uncontrolled extraction and an intolerance of high has been recorded.

Extraction of other species	Not relevant	Not relevant

Patella ulyssiponensis has no known relationships with species subject to extraction fisheries.

Additional information

Patella ulyssiponensis generally has a high recoverability. After the *Torrey Canyon* oil spill, the entire populations of certain beaches were wiped out by the uncontrolled use of dispersants. Even so, it took only 3-5 years for *Patella ulyssiponensis* to return to population sizes and distributions found before the oil spill (Southward & Southward, 1978).

Importance review

Policy/legislation

- no data -

Status

National (GB) importance	-	**Global red list (IUCN) category**	-

Non-native

Native	-		
Origin	-	**Date Arrived**	-

Importance information

Patella ulyssiponensis is harvested in the Azores for human consumption of the flesh. Regulation of extraction has prevented local extinction of this species in the Azores but the population has declined (Corte-Real *et al*., 2001; Martins *et al*., 1984). Limpets have been suggested as good bioindicators of heavy metal pollution (Bebiano *et al*., 2003; Catsiki *et al*., 1991).

Bibliography

Bebianno, M.J., Cravo, A., Miguel, C. & Morias, S., 2003. Metallothionein concentrations in a population of *Patella aspera*: variation with size. *Science of the Total Environment*, **301**, 151-161.

Bonner, T. M., Pyatt, F. B. & Storey, D. M., 1993. Studies on the motility of the limpet *Patella vulgata* in acidified sea-water. *International Journal of Environmental Studies*, **43**, 313-320.

Catsiki, V.A., Papathanassiou, E. & Bei, F., 1991. Heavy metal levels in characteristic benthic flora and fauna in the central Aegean Sea. *Marine Pollution Bulletin*, **22**, 566-569.

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 441 pp., Swindon: Water Research Council on behalf of EN, SNH, CCW, JNCC, SAMS and EHS. [UK Marine SACs Project.], http://www.ukmarinesac.org.uk/

Corte-Real, H.S.M., Hawkins, S.J. & Thorpe, J.P., 1992. Genetic confirmation that intertidal and subtidal morphs of *Patella ulyssiponensis aspera* Roding (Mollusca: Gastropoda: Patellidae) are conspecific. *Arquipelago*, **10**, 55-66.

Davies, M.S., 1992. Heavy metals in seawater: effects on limpet pedal mucus production. *Water Research*, **26**, 1691-1693.

Davies, P.S., 1969. Physiological ecology of *Patella* III. Desiccation effects. *Journal of the Marine Biological Association of the United Kingdom*, **49**, 291-304.

de Pirro, M., Chelazzi, G., Borghini, F. & Focardi, S., 2001. Variations in cardiac activity following acute exposure to copper in three co-occuring but differently zoned Mediterranean limpets. *Marine Pollution Bulletin*, **42**, 1390-1396.

de Pirro, M., Santini, G. & Chelazzi, G., 1999. Cardiac responses to salinity variations in two differently zoned Mediterranean limpets. *Journal of Comparative Physiology, B*, **169**, 501-506.

Delany, J., Myers, A.A. & McGrath, D., 1998. Recruitment, immigration and population structure of two coexisting limpet species in mid-shore tidepools, on the west coast of Ireland. *Journal of Experimental Marine Biology and Ecology*, **221**, 221-230.

Denny, M.A., 1989. Limpet shell shape that reduces drag: laboratory demonstration of a hydrodynamic mechanism and an exploration of its effectiveness in nature. *Canadian Journal of Zoology*, **67**, 2098-2106.

Evans, R.G., 1953. Studies on the biology of British limpets - the genus *Patella* on the south coast of England. *Proceedings of the Zoological Society of London*, **123**, 357-376.

Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore.* Cambridge: Cambridge University Press.

Fretter, V. & Graham, A., 1994. *British prosobranch molluscs: their functional anatomy and ecology*, revised and updated edition. London: The Ray Society.

Graham, A., 1988. *Molluscs: prosobranchs and pyramellid gastropods (2nd ed.).* Leiden: E.J. Brill/Dr W. Backhuys. [Synopses of the British Fauna No. 2]

Hayward, P., Nelson-Smith, T. & Shields, C. 1996. *Collins pocket guide. Sea shore of Britain and northern Europe.* London: HarperCollins.

Hayward, P.J. & Ryland, J.S. (ed.) 1995b. *Handbook of the marine fauna of North-West Europe.* Oxford: Oxford University Press.

Hoare, R. & Hiscock, K., 1974. An ecological survey of the rocky coast adjacent to the effluent of a bromine extraction plant. *Estuarine and Coastal Marine Science*, **2** (4), 329-348.

Howson, C.M. & Picton, B.E., 1997. *The species directory of the marine fauna and flora of the British Isles and surrounding seas.* Belfast: Ulster Museum. [Ulster Museum publication, no. 276.]

Jenkins, S.R., Beukers-Stewart, B.D. & Brand, A.R., 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. *Marine Ecology Progress Series*, **215**, 297-301.

Kinne, O. (ed.), 1980. *Diseases of marine animals.* vol. 1. *General aspects. Protozoa to Gastropoda.* Chichester: John Wiley & Sons.

Langston, W.J., Chesman, B.S., Burt, G.R., Hawkins, S.J., Readman, J. & Worsfold, P., 2003. Characterisation of European Marine Sites. Poole Harbour Special Protection Area. *Occasional Publication. Marine Biological Association of the United Kingdom*, **12**, 111.

Lincoln, R., Boxshall, G., & Clark, P., 1998. *A Dictionary of Ecology, Evolution and Systematics (2nd ed.).* Cambridge: Cambridge University Press

Little, C. & Kitching, J.A., 1996. *The Biology of Rocky Shores.* Oxford: Oxford University Press.

Martins, H.R., Santos, R.S. & Hawkins, S.J., 1987. Exploitation of limpets (*Patella* spp.) in the Azores with a preliminary analysis of the stocks. International Council for the Exploration of the Sea, Copenhagen (Denmark). ICES Council Meeting 1987 (collected papers).

Petpiroon, S. & Dicks, B., 1982. Environmental effects (1969 to 1981) of a refinery effluent discharged into Littlewick Bay, Milford Haven. *Field Studies*, **5**, 623-641.

Rogers, K.M., 2003. Stable carbon and nitrogen isotope signatures indicate recovery of marine biota from sewage pollution at Moa Point, New Zealand. *Marine Pollution Bulletin*, **46**, 821-827.

Santini, G., Bruschini, C., Pazzagli, L., Pieraccini, G., Moneti, G. & Chelazzi, G., 2001. Metabolic responses of the limpet *Patella caerula* (L.) to anoxia and dehydration. *Comparative Biochemistry and Physiology*, **130A**, 1-8.

Shin, P.K.S., 1988. Effects of a spill of bunker oil on the marine biological communities in Hong Kong. *Environment International*, **14**, 545-552.

Smith, J.E. (ed.), 1968. 'Torrey Canyon'. *Pollution and marine life.* Cambridge: Cambridge University Press.

Southward, A.J. & Southward, E.C., 1978. Recolonisation of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. *Journal of the Fisheries Research Board of Canada*, **35**, 682-706.

Tablado, A., Lopez Gappa, J.J. & Magaldi, N.H., 1994. Growth of the pulmonate limpet *Siphonaria lessoni* (Blainville) in a rocky intertidal area affected by sewage pollution. *Journal of Experimental Marine Biology and Ecology*, **175**, 211-226

Thompson, G.B., 1979. Distribution and population dynamics of the limpet *Patella aspera* (Lamarck) in Bantry Bay. *Journal of Experimental Marine Biology and Ecology*, **40**, 115-135.

Datasets

Bristol Regional Environmental Records Centre, 2017. BRERC species records recorded over 15 years ago. Occurrence dataset: https://doi.org/10.15468/h1ln5p accessed via GBIF.org on 2018-09-25.

Centre for Environmental Data and Recording, 2018. Ulster Museum Marine Surveys of Northern Ireland Coastal Waters. Occurrence dataset https://www.nmni.com/CEDaR/CEDaR-Centre-for-Environmental-Data-and-Recording.aspx accessed via NBNAtlas.org on 2018-09-25.

Cofnod – North Wales Environmental Information Service, 2018. Miscellaneous records held on the Cofnod database. Occurrence dataset: https://doi.org/10.15468/hcgqsi accessed via GBIF.org on 2018-09-25.

Conchological Society of Great Britain & Ireland, 2018. Mollusc (marine) data for Great Britain and Ireland - restricted access. Occurrence dataset: https://doi.org/10.15468/4bsawx accessed via GBIF.org on 2018-09-25.

Conchological Society of Great Britain & Ireland, 2018. Mollusc (marine) data for Great Britain and Ireland. Occurrence dataset: https://doi.org/10.15468/aurwcz accessed via GBIF.org on 2018-09-25.

Environmental Records Information Centre North East, 2018. ERIC NE Combined dataset to 2017. Occurrence dataset: http://www.ericnortheast.org.uk/home.html accessed via NBNAtlas.org on 2018-09-38

Fenwick, 2018. Aphotomarine. Occurrence dataset http://www.aphotomarine.com/index.html Accessed via NBNAtlas.org on 2018-10-01

National Trust, 2017. National Trust Species Records. Occurrence dataset: https://doi.org/10.15468/opc6g1 accessed via GBIF.org on 2018-10-01.

NBN (National Biodiversity Network) Atlas. Available from: https://www.nbnatlas.org.

OBIS (Ocean Biogeographic Information System), 2019. Global map of species distribution using gridded data. Available from: Ocean Biogeographic Information System. www.iobis.org. Accessed: 2019-03-21

South East Wales Biodiversity Records Centre, 2018. SEWBReC Molluscs (South East Wales). Occurrence dataset: https://doi.org/10.15468/jos5ga accessed via GBIF.org on 2018-10-02.

South East Wales Biodiversity Records Centre, 2018. Dr Mary Gillham Archive Project. Occurance dataset: http://www.sewbrec.org.uk/ accessed via NBNAtlas.org on 2018-10-02