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

Blow lug (*Arenicola marina*)

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

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Specimen of *Arenicola marina* with proboscis everted.
Photographer: Dr Matt Bentley
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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	Dr Harvey Tyler-Walters	**Refereed by**	Dr Matt Bentley
Authority	(Linnaeus, 1758)		
Other common names	-	**Synonyms**	-

Summary

Description

Arenicola marina is the familiar lugworm, much prized as bait by anglers. This sedentary polychaete has a firm, cylindrical body divided into a thoracic and an abdominal region. The head is small, with no appendages or eyes although a rough proboscis may be visible. The thoracic region consists of 19 parapodia bearing segments (with chaetae), of which the last 13 bear bushy gills. The abdominal region is narrower and consists of many segments lacking chaetae and gills. Apart from the head, each segment is divided by 5 rings (annuli). Adults reach between 12 and 20 cm in length and vary in colour from pink to dark pink, red, green, dark brown or black. Digs a U or J-shaped burrow (20-40 cm deep) with characteristic depressions at the head end (the 'blow hole') and a cast of defaecated sediment at the tail end. Feeds on detritus and micro-organisms in ingested sediment. The cast is large and often the colour of clean sand. Tolerates salinities down to 12 psu. Preyed on by flatfish and wading birds, which may 'nip' off the tail as it deposits casts. May be confused with *Arenicola defodiens* (the black lug) which is generally darker (usually black), longer (up to 270mm), burrows deeper (usually 40-70cm), rarely forms a 'blow hole', produces a finer, neater cast, prefers more exposed coasts rather than estuaries and differs in the number of annuli between the first 4 pairs of chaetae bearing segments and in the shape of the gills.

Recorded distribution in Britain and Ireland

Found on all coasts around Britain and Ireland and widely in north-west Europe.

Global distribution

Recorded from shores of western Europe, Norway, Spitzbergen, north Siberia, and Iceland. In the western Atlantic it has been recorded from Greenland, along the northern coast form the Bay of Fundy to Long Island. Its southern limit is about 40° N.

Habitat

Found from high water neap tidal level to the middle or lower shore in sand and muddy sand, living in a characteristic U or J-shaped burrow. Often reaches high abundances in sheltered estuarine sediments.

Depth range

Intertidal

Identifying features

- Anterior, thoracic region of 19 chaetigerous segments.
- Branching dorsal gills on segments 7-19.
- Posterior abdominal region narrow without gills and chaetae.
- Body firm and cylindrical.
- Almost all segments with 5 annuli.
- Head blunt, without appendages.
- Annulation pattern, chaetigerous segment i, 2 annuli, segment ii, 3 annuli, segment iii, 4 annuli, segment iv.

Additional information

Arenicola defodiens sp. nov. has recently been distinguished from *Arenicola marina* on the basis of the morphology of the gills, the annulation pattern between the first 4 chaetigerous segments, size, burrow depth, cast type and shape, colour, absence of a feeding depression and genetic polymorphism (see Cadman & Nelson-Smith, 1993). These two species may represent the 'laminarian' and 'littoral' forms respectively referred to by earlier authors.

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Biology review

Taxonomy

Phylum	Annelida	Segmented worms e.g. ragworms, tubeworms, fanworms and spoon worms
Class	Polychaeta	Bristleworms, e.g. ragworms, scaleworms, paddleworms, fanworms, tubeworms and spoon worms
Family	Arenicolidae	
Genus	Arenicola	
Authority	(Linnaeus, 1758)	
Recent Synonyms	-	

Biology

Typical abundance	Moderate density
Male size range	120-200mm
Male size at maturity	
Female size range	Medium(11-20 cm)
Female size at maturity	
Growth form	Vermiform segmented
Growth rate	See additional text
Body flexibility	High (greater than 45 degrees)
Mobility	
Characteristic feeding method	Sub-surface deposit feeder, Surface deposit feeder
Diet/food source	
Typically feeds on	Micro-organisms (bacteria), benthic diatoms, meiofauna, and detritus.
Sociability	
Environmental position	Infaunal
Dependency	Host for.
Supports	Independent Distomid cercariae and Coccidia.
Is the species harmful?	No

Biology information

- The anatomy of *Arenicola marina* was described in detail by Ashworth (1904).
- *Arenicola marina* burrows into sediment using its proboscis and muscular contractions of the first few segments. It forms a J-shaped burrow (see image) with a vertical shaft and horizontal limb in which the worm lies head first. *Arenicola marina* ingests sediment at head end of the burrow forming a feeding column and characteristic funnel or 'blow hole' on the surface (Wells, 1945; Zebe & Schiedek, 1996). Therefore, it feeds on material obtained from the sediment surface. The shape and different feeding characteristics of the funnel were discussed and photographed by Rijken (1979).
- *Arenicola marina* ingests small particles (<2mm) which stick to the proboscis papillae while

larger particles are rejected and accumulate in the vicinity of the burrow, often resulting in a characteristic layer of shell material below the burrow found in sediments populated by this species (Zebe & Schiedek, 1996; Riisgård & Banta, 1998).

- *Arenicola marina* feeds on micro-organisms (bacteria), meiofauna and benthic diatoms in the sediment and is also capable of absorbing dissolved organic matter (DOM) such as fatty acids through the body wall (Zebe & Schiedek, 1996).
- Feeding, defaecation and burrow irrigation is cyclic. Each cycle takes about 42 minutes in large worms but 15 min in smaller worms, depending on individual. Each cycle consists of defaecation (worm mainly in the tail-shaft), followed by rapid irrigation and a longer period of feeding, after which the worm defaecates again and the cycle repeats (Wells, 1949; Russell-Hunter, 1979; Riisgård & Banta, 1998)
- The burrow is irrigated (and therefore aerated) by intermittent cycles of peristaltic contractions of the body from the tail to the head end. Therefore, freshwater is taken in at the tail end and leaves by percolation through the feeding column.
- *Arenicola marina* can extract 32 -40% of the oxygen in burrow water, mainly through the gills but partly through the body surface. The blood has a high oxygen carrying capacity due to the presence of high concentrations of extracellular haemoglobin. At low tide, when supply of freshwater is not available, movement is reduced to a minimum.
- *Arenicola marina* is capable of anaerobic metabolism in hypoxic conditions (see Zeber & Schiedek, 1996 for review).
- Tail-nipping by flatfish, *Nereis virens*, and *Hediste diversicolor* results in loss of a few tail segments, which are not replaced, tail length being made up by increasing the length of the remaining segments. The tail is important for the storage of faeces. Storage of faeces minimises defaecation at the surface, and therefore resultant risk of predation. Tail-nipping results in decreased overall growth (de Vlas, 1979).
- Newell (1948) noted that the average length of adult *Arenicola marina* decreased overwinter then rapidly increased in spring to reach a maximum in September.
- Ashworth (1904) recorded the presence of Distomid cercariae and Coccidia in *Arenicola marina* from the Lancashire coast.

Habitat preferences

Physiographic preferences	Strait / sound, Sea loch / Sea lough, Ria / Voe, Estuary, Isolated saline water (Lagoon), Enclosed coast / Embayment
Biological zone preferences	Lower eulittoral, Mid eulittoral, Sublittoral fringe, Upper eulittoral
Substratum / habitat preferences	Fine clean sand, Mixed, Muddy gravel, Muddy sand, Saltmarsh, Sandy mud
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Strong 3 to 6 knots (1.5-3 m/sec.), Very Strong > 6 knots (>3 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Moderately exposed, Sheltered, Very sheltered
Salinity preferences	Full (30-40 psu), Reduced (18-30 psu), Variable (18-40 psu)
Depth range	Intertidal
Other preferences	No text entered
Migration Pattern	Non-migratory / resident

Habitat Information

Arenicola marina reaches its highest abundance at mid-tidal levels on muddy sandy shores, except in summer when another zone of abundance occurs on the upper shore due to migration of juveniles (see larval information). Population density is correlated with mean particle size and organic content of the sediment. *Arenicola marina* is generally absent from sediments with a mean particle size of <80µm and abundance declines in sediments >200µm (fine sand) because they can not ingest large particles. Its absence from more fluid muddy sediments is probably because they do not produce large amounts of mucus with which to stabilise their burrows. Populations are greatest in sands of mean particle size of 100µm. Between 100-200µm the biomass of *Arenicola marina* increases with increasing organic content (Longbottom, 1970; Hayward, 1994). However, juveniles prefer medium particle sizes (ca. 250 µm) over fine or coarse sand (see general biology - larval) (Hardege *et al.*, 1998).

Life history

Adult characteristics

Reproductive type	Gonochoristic (dioecious)
Reproductive frequency	Annual episodic
Fecundity (number of eggs)	100,000-1,000,000
Generation time	1-2 years
Age at maturity	1-2 years (see additional text)
Season	See additional text
Life span	5-10 years

Larval characteristics

Larval/propagule type	-
Larval/juvenile development	Oviparous
Duration of larval stage	Not relevant
Larval dispersal potential	1 km -10 km
Larval settlement period	Not relevant

Life history information

- Eggs and early larvae develop within the female burrow, however post larvae are capable of active migration by crawling, swimming in the water column and passive transport by currents e.g. Günther (1992) suggested that post-larvae of *Arenicola marina* were transported distances in the range of 1 km.
- Wilde & Berghuis (1979b) reported 316,000 oocytes per female with an average wet weight of 4g.
- Beukema & de Vlas, (1979) suggested a lifespan, in the Dutch Wadden Sea, of at least 5-6 years, and cite a lifespan of at least 6 years in aquaria. They also suggested an average annual mortality or 22%, an annual recruitment of 20% and reported that the abundance of the population had been stable for the previous 10 years. However, Newell (1948) reported 40% mortality of adults after spawning in Whitstable.

- Adults reach sexual maturity by their second year (Newell, 1948; Wilde & Berghuis, 1979) but may mature by the end of their first year in favourable conditions depending on temperature, body size, and hence food availability (Wilde & Berghuis, 1979).

Gametogenesis and spawning:

- Germ cells released from gonads at meiotic prophase I.
- Spermatogenesis and oogenesis occur within the coelomic cavity. Sperm are released into the coelomic cavity in packets or sperm morulae. Release of gametes from the body cavity, and in the case of sperm by the prior breakdown of morulae, is under endocrine control by a 'maturation factor'. The 'maturation factor' is released by a neurosecretory organ, the prostomium (Bentley & Pacey, 1992; Pacey 2000). Sperm maturation factor stimulates breakdown of sperm morulae and spawning.
- Spawning takes place within the burrow.
- Spawning of gametes occurs due to rhythmic contractions of the body wall, and the gametes are released via the nephridia (Bentley & Pacey, 1992).
- Sperm motility is stimulated by the change in pH as the sperm are released into seawater (i.e. from pH 7.3 in the coelomic cavity to pH 8.2 in seawater).
- Spawned sperm are flushed out of the burrow by pumping activity of the male, whilst oocytes are retained in the horizontal shaft of the female's burrow.
- After spawning males fasted for 2 days while females fasted for 3-4 weeks, presumably to avoid ingesting eggs and larvae (Farke & Berghuis, 1979).
- Once spawned sperm remain motile for over 5 hours at 14 °C. (Pacey, 2000), form puddles on the sediment surface and are dispersed by the incoming tide. Eggs (oocytes) are retained in the females burrow (Bentley & Pacey, 1992).
- Sperm swim intermittently, perhaps in response to light, and Pacey (2000) suggested that this may be an adaptation to downward swimming towards the eggs.
- Spermatogenesis, sperm maturation and oocyte maturation have been in studied in detail by Bentley & Pacey (1989), Bentley & Pacey (1992), Watson & Bentley (1995), and Watson & Bentley (1998). A comparative study of gametogenesis in *Arenicola marina* and *Arenicola defodiens* was carried out by Watson *et al.* (1998).

Factors influencing spawning:

- Spawning usually occurs in late autumn or early winter but may occur in early spring (Pacey, 2000).
- Spawning is inhibited by temperatures above 13 or 15 °C (depending on study) (Bentley & Pacey, 1992).
- Synchronous spawning is associated with spring or neap tides suggesting a correlation with tidal or lunar cycles (Howie, 1959; Bentley & Pacey, 1992).
- Watson *et al.*, (2000) examined *Arenicola marina* population on East Sands, St. Andrews and suggested that synchronous spawning was dependant on a number of environmental cues, i.e. once gametogenesis is complete (about late summer depending on population) a drop in sea temperature - of defined, but unknown magnitude - triggers endocrine stimulation of spawning. Synchronous spawning is then is triggered by spring tides, probably due to changes in hydrostatic pressure rather than lunar phase.
- Warm summer temperatures (ca May to July) may facilitate gametogenesis, due to increase metabolic rate and food availability, allowing the population to mature earlier and hence spawn earlier (Watson *et al.*, 2000).
- Watson *et al.* (2000) suggested that the East Sands population spawned preferentially in clement weather (high pressure, low rainfall and wind speed), when sperm dilution (due to

wave action) is minimal. Inclement weather coincident with spring tides resulted in the population wide spawning being aborted on the East Sands in 1996 (Watson *et al.*, 2000).
- Individuals within a given locality may spawn synchronously, e.g. at East Sands, St. Andrews, over a period of 13 years observation spawning time varied by 5 weeks, but was synchronous over a period of 4-5 days (Watson *et al.*, 2000).
- The exact timing of spawning varies between locations and some populations demonstrate protracted spawnings. For example, on sandy shores near St Andrews and Dublin spawning occurred between mid October to mid November, peaking in early November, whereas at Fairlie Sans, Millport spawning occurred between Apr and May and again in autumn (Howie, 1959; Bentley & Pacey, 1992). Dillon & Howie (1997) reported marked differences in timing of synchronous spawning or protracted spawnings in populations of *Arenicola marina* from the east coast of Ireland, even though separated by no more than 85 miles. The reported spawning periods of *Arenicola marina* were reviewed by Clay (1967; Table 1).

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 remove the *Arenicola marina* population. McLusky *et al.* (1983) examined the effects of bait digging on blow lug populations in the Forth estuary. Dug and infilled areas and unfilled basins left after digging re-populated within 1 month, whereas mounds of dug sediment took longer and showed a reduced population. Basins accumulated fine sediment and organic matter and showed increased population levels for about 2-3 months after digging. Overall recovery is generally regarded as rapid. However, Fowler (1999) pointed out that recovery may take longer on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if all the available substratum occupied by this species is removed, recovery may be protracted and a rank of high has been given. However, where the affected population is isolated or severely reduced (e.g. by long-term mechanical dredging), then recovery may be extended.

	Intolerance	Recoverability	Sensitivity	Confidence
Smothering	Tolerant	Not relevant	Not sensitive	Not relevant

Arenicola marina is a sub-surface deposit feeder that technically derives the sediment it ingests from the surface. It rapidly reworks and mixes sediment. It is unlikely to be perturbed by smothering by 5cm of sediment. However, it is likely to be intolerant of smothering by impermeable materials.

	Intolerance	Recoverability	Sensitivity	Confidence
Increase in suspended sediment	Low	Immediate	Not sensitive	Very low

Arenicola marina is unlikely to be perturbed by increased concentrations of suspended sediment since it lives in sediment and is probably adapted to re-suspension of sediment by wave action or during storms. Increased siltation by fine materials, however, may modify the nature of the substratum and render it unsuitable for the *Arenicola marina*. Decreases in siltation, however may result in reduced food supply for the blow lug which is partly dependant on organic particles and detritus collected on the sediment surface for food. Therefore a rank of low intolerance has been reported.

Decrease in suspended sediment

	Intolerance	Recoverability	Sensitivity	Confidence
Dessication	Not relevant	Not relevant	Not relevant	Not relevant

Arenicola marina is protected from desiccation because it lives in a deep, water filled burrow. However, early larvae live on mucilaginous tubes on the surface of the substratum on the upper shore and are likely to be more vulnerable to desiccation. Increased desiccation may depress the upper limit of their distribution and potentially increase mortality, however no information on this factor was found.

	Intolerance	Recoverability	Sensitivity	Confidence
Increase in emergence regime	Intermediate	Very high	Low	Low

Changes in emergence will probably not affect *Arenicola marina* directly. However, changes in emergence regime will alter the water retention and content of the sediment. Decreased emergence is likely to increase the extent of the population higher on the shore. Increased emergence, however, will increase the emersion time and hence the risk of hypoxia and anoxia (see deoxygenation). It is likely to result in a depressed upper limit of the species on the shore, especially in juveniles.

Decrease in emergence regime

Increase in water flow rate Intermediate Very high Low High

Changes in water flow rate are unlikely to affect *Arenicola marina* directly since it lives in a deep burrow. However, water flow rate and other hydrodynamics factors have a significant effect on the distribution of sediments of different grain size on sedimentary shores. Increased water flow deposits coarser sediments whereas reduced water flow rates will deposit finer sediments. Therefore, changes in water flow rate are likely to change the distribution and extent of *Arenicola marina* populations.

Decrease in water flow rate

Increase in temperature Intermediate Very high Low Moderate

Species dwelling in or on the surface of the sediment are likely to be affected by increased temperatures and direct sunlight, however, deeper burrowing species like *Arenicola marina* are protected from direct effects. Increased temperatures may affect infauna indirectly, by stimulating increased bacterial activity, increased oxygen consumption and therefore depletion of oxygen from the interstitial waters resulting in reduced oxygen levels (hypoxia) or absence of oxygen (anoxia) (see deoxygenation) in the sediment (Hayward, 1994). Wilde & Berghuis (1979) reported 20% mortality of juveniles reared at 5 °C, negligible at 10 and 15 °C but 50% at 20 °C and 90% at 25 °C. Sommer *et al.* (1997) examined sub-lethal effects of temperature and suggested a critical upper and lower temperature of 20 °C and 5 °C respectively in North Sea specimens. Above or below these critical temperatures specimens resort to anaerobic respiration. Sommer *et al.* (1997) noted that specimens could not acclimate to a 4 °C increase above the critical temperature. Therefore, *Arenicola marina* is probably intolerant of a short term acute change in temperature of 5 °C although it is unlikely to be directly affected due to its infaunal habit.
Temperature change may adversely affect reproduction. For example, spawning can be inhibited in gravid adults maintained above 15 °C (Bentley & Pacey, 1992; Watson *et al.*, 2000). Temperature change may affect maturation, spawning time and synchronisation of spawning and reproduction in the long-term (Watson *et al.*, 2000). Therefore, temperature change may affect recruitment in the long term and an intolerance of 'intermediate' has been recorded.

Decrease in temperature

Increase in turbidity Low Immediate Not sensitive Very low

Increased turbidity may reduce benthic diatom productivity and reduce this source of food for *Arenicola marina*. However, *Arenicola marina* also feeds on meiofauna, bacteria and organic particulates in the sediment, and is unlikely to be affected significantly.

Decrease in turbidity

Increase in wave exposure Intermediate Very high Low Low

The hydrodynamic regime has a significant effect on the distribution of sediments of different particle sizes and the slope of the shore. Decreases in wave exposure may increase accretion and hence increase the area of intertidal flat available to *Arenicola marina*. Conversely increased wave exposure may increase erosion, especially at the bottom of the shore, decreasing the extent of the available habitat for this species. The larval nursery areas may be particularly intolerant especially since the larvae inhabit the top few centimetres of the substratum. Similarly, increased wave action will increase sperm dilution and hence fertilization success, with potentially adverse effects on the population in the long term (Watson *et al.*, 2000).

Decrease in wave exposure

Noise	Tolerant	Not relevant	Not sensitive	Not relevant

Arenicola marina may respond to vibrations from predators or bait diggers by retracting to the bottom of their burrow. Strong vibrations may interfere with feeding. However, it is unlikely to sensitive to noise *per se*.

Visual Presence	Tolerant	Not relevant	Not sensitive	Not relevant

Arenicola marina lives in a burrow and therefore in permanent darkness. Although it can emerge to migrate to other areas its visual range is probably very limited.

Abrasion & physical disturbance	Intermediate	Very high	Low	Low

Arenicola marina lives in sediment to a depth of 20-40 cm and is therefore protected from most sources of abrasion and physical disturbance caused by surface action. However, it is likely be damaged by any activity (e.g. anchors, dredging) that penetrates the sediment.

Displacement	Low	Immediate	Not sensitive	Low

Displacement from the sediment is likely to expose *Arenicola marina* to an increased risk of predation. However, once on the substratum surface *Arenicola marina* is capable of burrowing back into the sediment and passive migration to suitable sediment (see extraction).

Chemical Pressures

	Intolerance	Recoverability	Sensitivity	Confidence
Synthetic compound contamination	High	High	Moderate	Low

The xenobiotic ivermectin (used to control parasitic infestations in livestock including sea lice in fish farms), degrades slowly in marine sediments (half life >100 days). Ivermectin was found to produce a 10 day LC_{50} of 18µg ivermectin /kg of wet sediment in *Arenicola marina*. Sub-lethal effects were apparent between 5 - 105 µg/kg. Cole *et al.* (1999) suggested that this indicated a high intolerance. Naphthalene (a poly-aromatic hydrocarbon, PAH) was found to accumulate from the water column rather than sediment, however it was nearly completely lost from *Arenicola marina* within 24 hrs (Cole *et al.* 1999). Bryan & Gibbs (1991) reviewed the reported effects on tributyl tin (TBT). They reported that *Arenicola cristata* larvae were unaffected by 168 hr exposure to 2000 ng TBT/ l seawater and was probably relatively tolerant. However, given this species intolerance to ivermectin an intolerance of high has been reported.

Heavy metal contamination	Low	Very high	Very Low	Moderate

Arenicola marina is presently used routinely as a standard bioassay organism for assessing the toxicity of marine sediments (Bat & Raffaelli, 1998). At high concentrations of Cu, Cd or Zn the blow lug left the sediment (Bat & Raffaelli, 1998). Bryan (1984) suggested that polychaetes are fairly resistant to heavy metals, based on the species studied. Short term toxicity in polychaetes was highest to Hg, Cu and Ag, declined with Al, Cr, Zn and Pb whereas Cd, Ni, Co and Se the least toxic. Exposure to 10 ppm Cd in seawater halted feeding in *Arenicola marina* although they continued at 1 ppm (Rasmussen *et al.*, 1998). Rasmussen *et al.*, (1998) pointed out that bioturbation by the blow lug increases the rate of uptake of Cd from the water to the sediment, however, where sediments were already contaminated, bioturbation ensured that some fraction of the contaminant would be mobilised to the surface sediment and the environment. *Arenicola marina* was found to accumulate As, Cd, Sb, Cu, and Cr when exposed to pulverised fuel ash (PFA) in sediments (Jenner & Bowmer, 1990). Jenner & Bowmer (1990) also noted 95% mortality when exposed to 100% PFA for 90 days and 75% exposed to 50% PFA for the same period, however, the above mortality may have been due to the unsuitability of PFA as a substrate rather than the heavy metal contamination. The following toxicities have been reported in *Arenicola marina*:

- no mortality after 10 days at 7 µg Cu /g sediment, 23µg Zn/g and 9µg Cd /g;
- median lethal concentrations (LC_{50})of 20 µg Cu/g, 50 µg Zn/g, and 25 µg Cd/g (Bat & Raffaelli, 1998).

Hydrocarbon contamination	Intermediate	High	Low	High

Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general, on soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected. Hailey (1995) cited substantial kills of *Nereis*, *Cerastoderma*, *Macoma*, *Arenicola* and *Hydrobia* as a result of the *Sivand* oil spill in the Humber estuary in 1983. Levell (1976) examined the effects of experimental spills of crude oil and oil: dispersant (BP1100X) mixtures on *Arenicola marina*. Single spills caused 25-50% reduction in abundance and additional reduction in feeding activity. Up to 4 repeated spillages (over a 10 month period) resulted in complete eradication of the affected population either due to death or migration out of the sediment. Levell (1976) noted that recolonization was inhibited but not prevented. Prouse & Gordon (1976) examined the effects of surface fuel oil contamination and fuel oil : sediment mixtures on the blow lug in the laboratory. They found that blow lug was driven out of the sediment by waterborne concentration of >1 mg/l or sediment concentration of >100 µg/g. Worms forced out of sediment may be able to migrate out of affected area but will be exposed to severe predation risk, especially in daylight. Seawater oil concentrations of 0.7 mg oil /l reduced feeding after 5hrs and all worms exposed for 22hrs to 5mg/l oil left the sediment and died after 3 days. However, their sample size, in this experiment, was very small (6 worms). Sediment concentration >10µg/g could reduce feeding activity. Therefore, an intolerance of intermediate has been reported. *Arenicola marina* can recolonize sediment relatively quickly, within 1 month (see 'Extraction'). However contaminated sediments would probably take longer to recover, so that a recovery of high has been reported.

Radionuclide contamination		Not relevant		Not relevant

Kennedy *et al.* (1988) reported levels of ^{137}Cs in *Arenicola* sp. of 220-440 Bq/kg from the Solway Firth. However, there is little evidence on the biological effects of radionuclides on marine species (Cole *et al.*,1999).

Changes in nutrient levels	Intermediate	High	Low	Low

The abundance and biomass of *Arenicola marina* increases with increased organic content in their favoured sediment (Longbottom, 1970; Hayward, 1994). Therefore, moderate nutrient enrichment may be beneficial. However, increasing nutrient enrichment may result in a well studied succession from the typical sediment community, to a community dominated by opportunist species (e.g. capitellids) with increased abundance but reduced species richness and eventually to abiotic anoxic sediments (Pearson & Rosenberg, 1978). Indirect effects may include algal blooms and the growth of algal mats (e.g. of *Ulva* sp.) on the surface of the intertidal flats. Algal mats smother the sediment, reducing water and oxygen exchange and resulting in localised hypoxia and anoxia when they die. Algal blooms have been implicated in mass mortalites of lugworms, e.g. in South Wales where up to 99% mortality was reported (Holt *et al.* 1995; Olive & Cadman, 1990; Boalch, 1979). Feeding lug worm were present, and exploitable by bait diggers within 1 month, suggesting rapid recovery, probably by migration from surrounding areas or juvenile nurseries. However, Cryer *et al.* (1987) reported no recovery for 6 months over summer after mortalities due to bait digging.

Increase in salinity	Low	Immediate	Not sensitive	Moderate

Once the salinity of the overlying water drops blow about 55% seawater (about 18psu) *Arenicola marina* stops irrigation, and compresses itself at the bottom of its burrow. It raises its tails to the head of the burrow to 'test' the water at intervals, about once an hour. Once normal salinities return they resume usual activity (Shumway & Davenport, 1977; Rankin & Davenport,1981; Zebe & Schiedek, 1996). This behaviour, together with their burrow habitat, enabled the lugworm to maintain its coelomic fluid and tissue constituents at a constant level, whereas individuals exposed to fluctuating salinities outside their burrow did not (Shumway & Davenport, 1977). Environmental fluctuations in salinity are only likely to affect the surface of the sediment, and not deeper organisms, since the interstital or burrow water is little affected. However, lugworms may be affected by low salinities at low tide after heavy rains. *Arenicola marina* was able to osmoregulate intracellular and extracellular volume within 72 - 114 hrs by increased urine production and increased amino acid concentration in response to hypo-osmotic shock (low salinity) (see Zebe & Schiedek, 1996). *Arenicola marina* exposed to hyper-osmotic shock (47 psu) loose weight, but are able to regulate and gain weight within 7-10 days (Zebe & Schiedek, 1996). However, *Arenicola marina* is unable to tolerate salinities below 24 psu and is excluded from areas influenced by freshwater runoff or input (e.g. the head end of estuaries) where it is replaced by *Hediste diversicolor* (Hayward, 1994).
Arenicola marina in the Baltic are more tolerant of reduced salinity. For example, Barnes (1994) reports that *Arenicola marina* occurs at salinities down to 18 psu in Britain, but survives as low as 8 psu in the Baltic, whereas Shumway & Davenport (1977) reported that this species cannot survive less than 10 psu in the Baltic. The reported salinity tolerance in the Baltic is probably a local adaptation.

Decrease in salinity

Changes in oxygenation	Low	Immediate	Not sensitive	High

Arenicola marina is subject to reduced oxygen concentrations regularly at low tide and is capable of anaerobic respiration. Transition from aerobic to anaerobic metabolism takes several hours and is complete within 6-8 hrs, although this is likely to be the longest period of exposure at low tide. Fully aerobic metabolism is restored within 60 min once oxygen is returns (Zeber & Schiedek, 1996). This species was able to survive anoxia for 90 hrs in the presence of 10 mmol/l sulphide in laboratory tests (Zeber & Schiedek, 1996). Hydrogen sulphide (H_2S) produced by chemoautotrophs within the surrounding anoxic sediment and may, therefore, be present in *Arenicola marina* burrows. Although the population density of *Arenicola marina* decreases with increasing H_2S, *Arenicola marina* is able to detoxify H_2S in the presence of oxygen and maintain low internal concentration of H_2S. At high concentrations of H_2S in the lab (0.5, 0.76 and 1.26 mmol/l) the lugworm resorts to anaerobic metabolism (Zeber & Schiedek, 1996). At 16 °C *Arenicola marina* survived 72 hrs of anoxia but only 36 hrs at 20 °C. Tolerance of anoxia was also seasonal, and in winter anoxia tolerance was reduced at temperatures above 7 °C. Juveniles have a lower tolerance of anoxia but are capable of anaerobic metabolism (Zebe & Schiedek, 1996). However, *Arenicola marina* has been found to be unaffected by short periods of anoxia and to survive for 9 days without oxygen (Borden, 1931 and Hecht, 1932 cited in Dales, 1958; Hayward, 1994). Therefore, this species is likely to have a low intolerance if exposed to oxygen concentration as low as 2mg/l.

Biological Pressures

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

Ashworth (1904) recorded the presence of distomid cercariae and Coccidia in *Arenicola marina* from the Lancashire coast. However, no information concerning infestation or disease related mortalities was found.

	Intolerance	Recoverability	Sensitivity	Confidence
Introduction of non-native species		Not relevant		Not relevant

No non-native species likely to compete with *Arenicola marina* were found.

	Intolerance	Recoverability	Sensitivity	Confidence
Extraction of this species	Intermediate	Very high	Low	High

Fowler (1999) reviewed the effects of bait digging on intertidal fauna, including *Arenicola marina*. Diggers have been reported to remove 50 or 70% of the blow lug population. Heavy commercial exploitation in Budle Bay in winter 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m▯. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al.* (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Mechanical lugworm dredgers have been used in the Dutch Wadden Sea where they removed 17-20 million lugworm/year. However, when combined with hand digging the harvest represented only 0.75% of the estimated population in the area. A near doubling of the lugworm mortality in dredged areas was reported, resulting in a gradual substantial decline in the local population over a 4 year period. The effects of mechanical lugworm dredging is more severe and can result in the complete removal of *Arenicola marina* (Beukema, 1995; Fowler, 1999). Beukema (1995) noted that the lugworm stock recovered slowly reaching its original level in at least three years. McLusky *et al.* (1983) examined the effects of bait digging on blow lug populations in the Forth estuary. Dug and infilled areas and unfilled basins left after digging re-populated within 1 month, whereas mounds of dug sediment took showed a reduced population. Basins accumulated fine sediment and organic matter and showed increased population levels for about 2-3 months after digging. Overall recovery is generally regarded as rapid. However, Fowler (1999) pointed out that recovery may take longer on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid and a rank of 'very high' has been given. However where the affected population is isolated or severely reduced (e.g. by long-term mechanical dredging), then recovery may be extended.

	Intolerance	Recoverability	Sensitivity	Confidence
Extraction of other species	Intermediate	Very high	Low	Low

Mechanical dredging for shellfish such as cockles (*Cerastoderma edule*) probably damages or kills *Arenicola marina* where they co-occur. However, no direct evidence was found. Mechanical harvesting of shellfish and bait in the intertidal is likely to have indirect effects by causing pits or trenches in the sediment. (Moore, 1991; Gubbay & Knapman, 1999). These can potentially form channels that increase local erosion of the sediment and hence loss of intertidal habitat for *Arenicola marina*.

Additional information

Importance review

Policy/legislation

- no data -

Status

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

Non-native

Native	-		
Origin	-	**Date Arrived**	-

Importance information

- *Arenicola marina* is an important food source for wading birds (e.g. curlew (*Numenius arquata*), bar-tailed godwit (*Limosa lapponica*) and oystercatcher (*Haematopus ostralegus*)), flatfish, and ragworm (*Nereis virens* and *Hediste diversicolor*). However, *Hediste diversicolor* is principally a detritivore and too small to affect adult blow lug (Matt Bentley, pers. comm.).
- *Arenicola marina* is collected, commercially and by individuals for bait, usually by hand digging or bait pumping although the use of JCBs by commercial diggers has been known. Professional and local bait diggers may work over 200m^2 of sediment per tide. Bait diggers have been estimated to remove 50 or 70% of bait. Commercial diggers may travel considerable distances to sites and have been reported to dig out bait populations (Fowler, 1999).
- Mechanical lugworm dredgers have been used in the Dutch Wadden Sea where they removed 17-20 million lugworm/year. However, when combined with hand digging the harvest represented only 0.75% of the estimated population in the area. A near doubling of the lugworm mortality in dredged areas was reported, resulting in a gradual substantial decline in the local population over a 4 year period (Fowler, 1999).
- Reworking of the sediment (bioturbation) by *Arenicola marina* has strong negative, density dependant, effects (interference competition) on the density of *Corophium volutator* and the juveniles of many worm and bivalve species (Flach, 1992). Irrigation of its burrow increases the rate of exchange of water (and oxygen) between sediment porewater and overlying water by 10 - 20 fold. Reworking of the surface sediment (bioturbation) by *Arenicola marina* increase the penetration of oxygen into the upper 2 -10cm of sediment together with rapid mixing of sediment particles, except for large particles which accumulate under the burrows. (Riisgård & Banta, 1998). Bioturbation by this species may inhibit or enhance meiofauna and micro-organisms, depending on species, increase aerobic decomposition but decrease anaerobic decomposition, and affect the sediment chemistry and nutrient cycling between the sediment and overlying water (Riisgård & Banta, 1998).
- Bioturbation by this and other species affects the cycling and retention of contaminants such as hydrocarbons and heavy metals within the sediment (Pocklington & Wells, 1992; Rasmussen *et al*., 1998).
- *Arenicola marina* is presently used routinely as a standard bioassay organism for assessing

the toxicity of marine sediments (Pocklington & Wells, 1992; Bat & Raffaelli, 1998).

- *Arenicola marina* burrows are a unique microhabitat for a number of meiofaunal species, for example 26 different species of meiobenthic Platyhelminthes (flatworms) were reported from different regions of the burrow in the intertidal mudflats of Sylt, North Sea (Reise, 1987).

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