



MarLIN

Marine Information Network

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

European spiny lobster (*Palinurus elephas*)

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

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Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [<https://www.marlin.ac.uk/species/detail/1145>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

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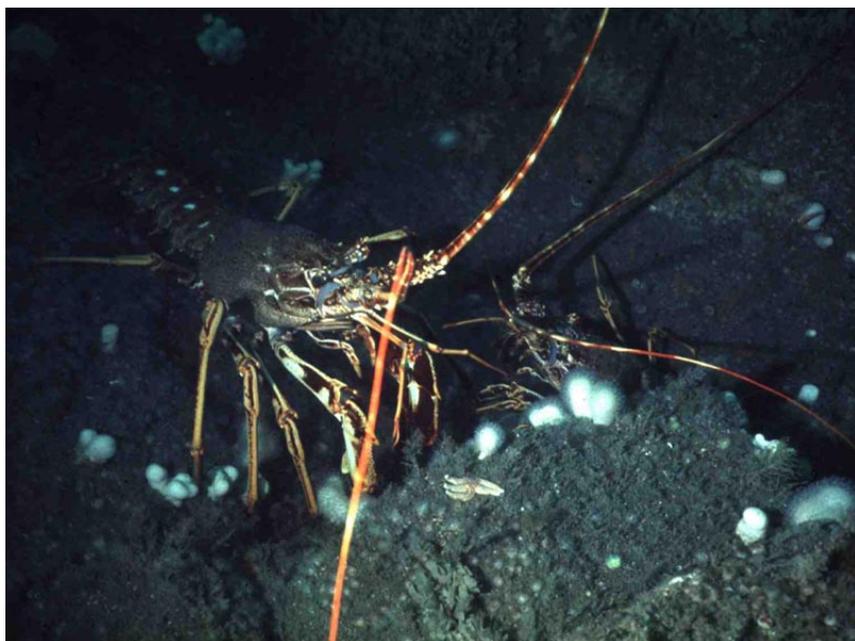
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Two spiny lobsters.
 Photographer: Keith Hiscock
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See online review for
 distribution map

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

Researched by	Eliza Gibson-Hall, Angus Jackson & Charlotte Marshall	Refereed by	Dr Keith Hiscock
Authority	(Fabricius, 1787)		
Other common names	Rock lobster, Crayfish, Crawfish	Synonyms	<i>Palinurus vulgaris</i> Gruvel, 1911

Summary

🔍 Description

A large spiny lobster, growing up to 60 cm in total length, with a stout, heavily armoured body. The colour is usually orange dorsally with darker spines and white underneath but brown, sandy and purple morphs are occasionally found (Hunter *et al.*, 1996; Hunter, 1999). It has numerous sharp spines on the carapace, over much of the abdomen and on the larger appendages. There are two long antennae and small hook-like claws.

📍 Recorded distribution in Britain and Ireland

The main populations are confined to the west coast of Scotland, the extreme south-west coasts of England & Wales and the west coast of Ireland. See 'additional information' in the Habitat section.

📍 Global distribution

South and west coasts of the British Isles, south to the Azores, the western Mediterranean, Adriatic Sea and the Aegean Sea.

🏠 Habitat

Lives subtidally on rocky, exposed coasts in the circalittoral zone.

↓ Depth range

5-400m

Q Identifying features

- Carapace covered with forward-directed spines; supra-orbital spines particularly prominent.
- Antennal stalks very heavy and spiny; flagellum stout, tapering and longer than the body.
- Typically orange colouration but may also be brown, sandy or purple.
- There are two large symmetrical white blotches on the tergites of somites 1-5, a single central blotch on the last segment and two blotches on the telson.
- Small hook-like claws.

🏛️ Additional information

Also known in Britain as the crawfish, crayfish, spiny lobster or rock lobster, and the langouste rouge (red spiny lobster), langouste commune or langouste royale (royal spiny lobster) in France. Spiny lobsters were intensively fished by netting and diving in the late 1960s and early 1970s leading to local extinctions in south-west Britain in particular. First signs of recovery did not occur until 2014 when large numbers of recently settled individuals were seen in locations from where they had been absent for over 40 years. A similar recruitment was observed at the same time in Brittany. The newly settled lobsters have grown and recruitment has continued (Keith Hiscock, pers. comm.).

When placed in a tank with predator species *Octopus vulgaris*, *Palinurus elephas* undertook chemosensory behaviour to respond to the octopus odour (Gristina *et al.*, 2011). They were subsequently able to detect the odour amongst a mixture of different odours and avoid the predator. Female lobsters 'stridulate'. This is a creaking noise from the base of the antennae. as a result, they are known as 'creakers' in west Wales. The noise attracts males. The acoustic signals emitted by *Palinurus elephas* is within the range of ultrasonic frequencies (20-55 kHz) (Edmonds *et al.*, 2016). Palero *et al.* (2008) found that the two northernmost Atlantic localities in their study (Western Scotland and Western Ireland) were clearly genetically differentiated from three other Atlantic localities (southwestern England, Brittany and the Bay of Biscay).

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Biology review

☰ Taxonomy

Phylum	Arthropoda	Arthropods, joint-legged animals, e.g. insects, crustaceans & spiders
Order	Decapoda	Crabs, shrimps, prawns, crayfish and lobsters
Family	Palinuridae	
Genus	Palinurus	
Authority	(Fabricius, 1787)	
Recent Synonyms	Palinurus vulgaris Gruvel, 1911	

🌿 Biology

Typical abundance	Data deficient
Male size range	40-60 cm (TL)
Male size at maturity	8-8.5 cm (CL)
Female size range	Medium-large(21-50 cm) (TL)
Female size at maturity	7-8 cm (CL)
Growth form	Articulate
Growth rate	See additional information
Body flexibility	None (less than 10 degrees)
Mobility	Crawler / Walker, Mobile
Characteristic feeding method	Scavenger, Searcher / forager
Diet/food source	Omnivore
Typically feeds on	Echinoderms, small gastropods and bivalves, microalgae, shrimp larvae, bryozoans, annelids.
Sociability	Gregarious
Environmental position	Epibenthic, Epifaunal
Dependency	Independent.
Supports	Substratum Encrusting species such as <i>Circeis armonicana</i> and <i>Spirorbis spirorbis</i> (tube worms), <i>Anomia ephippium</i> (saddle oyster) and <i>Electra pilosa</i> (a bryozoan). Stalked barnacles have been recorded from the antennae.
Is the species harmful?	No

🏛️ Biology information

Size

Size is measured as total length (TL) while carapace length (CL) is the measurement usually used for fisheries management. The maximum overall total length is about 60 cm, although more commonly 40 – 50 cm, and the carapace length of males and females ranges between 8.5-19.3 cm and 7.9-18 cm respectively. On average, larger maximum sizes have been recorded in the Atlantic populations compared to the Mediterranean. Sexual maturity in females has been shown to inhibit

further growth. This is thought to be due to the reproductive investment (Follesa *et al.*, 2007).

Growth

Growth rate and age of individuals still remains poorly known with some tagging studies of largish individuals suggesting growth rates of less than 1 mm CL/year, whilst others suggest 12 mm a moult. There are discrepancies in growth rate between the Mediterranean and Atlantic populations as well as between authors. Mercer (PhD thesis, 1973) found a mean annual size increase in females at 1.2 cm CL/year in an Irish population. This is marginally lower than males from the same population (1.22 cm CL/year) (Mercer, 1973; cited in Hunter, 1999). Other growth rate estimates suggest an increase of 2-14% of CL with each moult (Campillo & Amadei, 1978) or as low as 0.9 mm CL/year (Hiscock *et al.*, 2011). Growth increments are also thought to decrease as individuals approach their maximum size and are likely to vary with temperature. Hunter (1999) suggested that growth rates were higher in warmer waters. However, this is contrary to a review by Goñi & Latrouite (2005) that found faster growth rates in the Atlantic than the Mediterranean. In Pembrokeshire, the largest adult recorded in recent surveys had a carapace length of 15 cm (Jones, 2012). If the growth rate is lower than predicted, this may have further implications on the exact age of individuals.

Moulting

In Britain and Ireland, females moult in late summer between July and September (Hepper, 1977; Ansell & Robb, 1977; Hunter *et al.*, 1996). The moult cycle of males in Britain and Ireland seems to be less clear. Hunter *et al.* (1996) reported that males have a moult peak in September coinciding with the female moult. According to Hepper (1977) and Hunter (1999), male *Palinurus elephas* in Britain and Ireland moult mainly in the winter months, although Hunter (1999) also states that males moult throughout the year. Soft males have been found throughout the year with a higher abundance in winter (Gachardo, 2006). Juveniles moult around 8-12 times during their first year post-settlement. Each moult results in a 2 mm increase in CL (Groeneveld *et al.*, 2013). Moulting frequency decreases with age and after sexual maturity is reached, especially in females (Hunter, 1991).

Mobility and sociability

Palinurus elephas is more active at night, particularly for foraging (Diaz *et al.*, 2001; Goñi & Latrouite, 2005). These nocturnal movements are thought to be linked to the moon phase as catches of the spiny lobster are reduced under a full moon (Goñi *et al.*, 2001). Very few individuals have been observed out of their shelter during daylight hours suggesting a strong circadian rhythm (Diaz *et al.*, 2001). They leave their shelters for both feeding and reproduction (Goñi & Latrouite, 2005). *Palinurus elephas* typically crawls on the substratum but may swim occasionally. Adults are solitary or occur in pairs and small groups. Mercer (1973, cited in Hunter, 1999) describes the species as 'typically gregarious' (sociable). The homing ability of *Palinurus elephas* appears to be minimal with a range of only 7 m². The majority (90%) of individuals return to their resident shelter after foraging at night and nocturnal activity was reported to start an hour before sunset and end an hour before sunrise (Groeneveld *et al.*, 2013).

Migration

Migrations may be triggered by seasonal changes in sea temperature as well as light intensity (Miller, 1990). However, mass migrations appear to be missing in this species (Follesa *et al.*, 2007). Instead, several observations suggest that the species makes active annual migrations to and from

deeper water (Ansell & Robb, 1977; Hunter, 1999).

In the Atlantic, females move to deeper waters during egg development and return inshore prior to egg hatching (Goñi *et al.*, 2001). Males are also thought to make onshore-offshore migrations although the timing in relation to female migrations is contentious (Goñi *et al.*, 2001). The populations off the west of Ireland (except perhaps for large males) move offshore into deeper waters late in the year to overwinter and return back inshore in spring (Mercer, 1973, cited in Hunter, 1999). Longer distances are travelled by sexually immature males and females (CL 5.4-8 cm) suggesting that sexually mature individuals are more resident/sedentary (Follesa *et al.*, 2009). This is shown in the high site fidelity and limited movement of these species (Follesa *et al.*, 2011) with movement mainly restricted to 2.5 km/yr (Goñi & Latrouite, 2005). However, individuals can forage beyond the boundaries of certain Marine Protected Areas making the species vulnerable to fishing in those areas.



Habitat preferences

Physiographic preferences	Offshore seabed, Open coast
Biological zone preferences	Circalittoral, Data deficient
Substratum / habitat preferences	Artificial (man-made), Bedrock, Large to very large boulders, Small boulders, Wrecks
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Extremely exposed, Very exposed, Very sheltered
Salinity preferences	Full (30-40 psu)
Depth range	5-400m
Other preferences	Small individuals (CP < approx. 8 cm) shelter in fissures and holes. Larger individuals are seen under ledges, i.e. more open situations.
Migration Pattern	Seasonal (environment), Seasonal (reproduction)

Habitat Information

Around Britain and Ireland, the species is recorded on western seaboard eastwards to the Isle of Wight including on the Welsh coast of the Irish Sea and all around Orkney and Shetland and south in the North Sea to the Scottish border. The occasional isolated record from the east coast of Scotland suggests that larvae penetrate into and survive in the North Sea, presumably during periods when North Atlantic oceanic water intrudes further round into the North Sea (Hepper, 1977).

The species is usually found from the open coast to offshore rock where salinity is likely to be full (30-40 psu) (Ceccaldi & Latrouite, 2000). The typical depth range of the species is between 5 and 70 m (Ansell & Robb, 1977; Ingle, 1997) although it has been recorded at depths of 160 m (Noel, 1999).

In Pembrokeshire, *Palinurus elephas* was observed at depths of between 11.9 m and 22.8 m. The majority of individuals (77%), were recorded at 14-18 m (below chart datum) (Jones, 2012). The largest density of *Palinurus elephas* was found in the habitats with the highest number of rocky reefs and crevices (Jones, 2012). No records were found at less rocky sites and the crawfish were usually found close together. The highest number recorded in one day at a single site was eight; all

juveniles and five were found in a single gully together (Jones, 2012). All *Palinurus elephas* collected by Ansell and Robb (1977) were from areas of strong tidal currents on shallow inshore reefs that were interspersed with steep vertical rock faces. However, the species has also been recorded from finer sediments at the edge of *Zostera marina* beds in Salcombe Harbour (MBA, 1957). Juveniles have been found in seagrass beds (Giadone *et al.*, 2006).

Life history

Adult characteristics

Reproductive type	Gonochoristic (dioecious)
Reproductive frequency	Annual protracted
Fecundity (number of eggs)	See additional information
Generation time	Insufficient information
Age at maturity	Female: 4-5 years, Male: Variable
Season	July - October
Life span	21-50 yrs

Larval characteristics

Larval/propagule type	Phyllosoma, Puerulus
Larval/juvenile development	Oviparous
Duration of larval stage	1-6 months
Larval dispersal potential	>1000m
Larval settlement period	Insufficient information

Life history information

Lifespan

The maximum estimated lifespan is up to 25 years with reproductive maturity occurring at approximately 5 years in the Mediterranean (Marin 1987). In Pembrokeshire, the majority of individuals measured 10-12 cm and were estimated at 8-10 years old but juveniles were lacking (Jones, 2012).

Maturity

In a marine reserve in the Mediterranean, Goñi *et al.* (2003) found that female *Palinurus elephas* were able to reproduce at 7.6-7.7 cm CL and males were sexually mature at 8.25 cm CL. This size-specific fecundity was considered to be comparable to a lightly fished population off Ireland. In Britain and Ireland, size at maturity is generally larger (Hunter, 1999). In Cornwall, Hunter *et al.* (1996) reported the smallest berried female measured 9 cm CL, whereas in Wales the smallest berried female measured 12.1 cm CL. The mean size of female, male and berried female *Palinurus elephas* in Cornwall was reported as 12.5, 13.2 and 13.5 cm respectively, and 15.6, 13.9 and 13.9 cm respectively in Wales (Hunter *et al.*, 1996). Mercer (1973, cited in Hunter, 1999) found that 50% of the female population reached maturity at 8.2-8.6 cm CL in Irish *Palinurus elephas*, the

smallest measuring ca 7 cm CL.

Female *Palinurus elephas* are thought to usually be mature by the time they recruit into the fishery (Hunter *et al.*, 1996). Females are defined as physiologically mature when their ovaries reach 'stage 4' or higher during the reproductive season (Marin, 1987). For females, the age at which maturity is reached is around 4-5 years (Goñi *et al.*, 2003). The relationship between gonad width and body size is calculated to estimate maturity in males, however, it is difficult to estimate an average size and or age at which males reach maturity due to the degree of variation (Goñi *et al.*, 2003).

Mating

Mating is usually preceded by a 'pre-mating' moult, which occurs up to four weeks earlier (Ceccaldi & Latrouite, 1994). When the female is ready to mate, she emits a specific noise (stridulation) that attracts a mate (Mercer, 1973, cited in Ceccaldi & Latrouite, 1994). This mating call can attract males from a distance of 15-20 m. The noise ceases when a suitably sized male reaches the female. The male then deposits a spermatophore below the genital opening of the female.

Mating occurs between June and October in the Atlantic (Goñi & Latrouite, 2005), and females bearing spermatophores have been reported from August to October in Britain and Ireland (Hepper, 1977; Ansell & Robb, 1977; Hunter, *et al.*, 1996; Hunter, 1999). In laboratory experiments, Ansell & Robb (1977) found that eggs were released 7-10 days after the deposition of the spermatophore. As the eggs are laid, the spermatophores are torn with the claw on the fifth pereopods (Mercer, 1973, cited in Hunter *et al.*, 1996), thereby fertilizing the eggs. Single males in breeding tanks usually mate with several females and spawning occurs on the day of mating (Kittaka, 1997). Eggs are retained on the abdomen of the female for eight months prior to hatching (Hunter, 1999; Mercer, 1973).

Reducing the numbers of males in the population can result in the remaining males being unable to produce enough sperm to successfully fertilise. Sperm limitation can become an issue if large females are unable to find a suitable male to mate with either through reduced numbers of males due to fishing mortality or due to a lack of males of a suitable size with which to mate. Egg production can also be reduced due to an insufficient amount of sperm. Successful mating in crawfish only occurs where the mating pairs are similar in size (Mouat & Shelmerdine, 2012).

Fecundity

Fecundity in *Palinurus elephas* is influenced by the size of the female, with heavier specimens producing more eggs (Ceccaldi & Latrouite, 1994). Goñi *et al.* (2003) reported fecundity in a marine reserve in the western Mediterranean to be between ca 23,000 and 202,000 eggs. This is generally three to five times lower than fecundity in many other spiny lobster populations (Hunter, pers. comm. & Groeneveld *et al.*, 2013). *Palinurus elephas* carry fewer eggs than other genera of the same family (*Panulirus* and *Jasus*) but the eggs of *Palinurus elephas* are larger. Females of 10.5-11 cm CL in size contribute the most to egg production of a population. Larger females produce, on average, five times more eggs and larger larvae compared to smaller females (Goñi *et al.*, 2003). In contrast, reduced male size has not been shown to affect their mating success. *Palinurus elephas* is more vulnerable to stress during mating and egg production (Ansell & Robb, 1977). Mercer (1973) estimated a mean egg loss of 10% for an 8-month incubation period for Atlantic, mature, females. This suggests that loss of eggs could be positively correlated with temperature due to a stress response.

Larval ecology

Incubation in the Atlantic is typically nine months, after which, the eggs hatch in early summer (Hunter, 1999). In Cornwall, eggs were laid in late summer/autumn and hatched the following spring / early summer (Hepper, 1977). Most eggs have hatched by June in Wales and Cornwall (Hunter *et al.*, 1996). Hatching takes two to eight days (Hunter, 1999). In Scotland, hatching was thought to occur in April and May (Ansell & Robb, 1977). There is only one clutch per year. In the Mediterranean, incubation lasts for only five months, probably reflecting warmer water temperatures (Hunter, 1999).

Larvae measure 2.9-3.9 mm TL at hatching, and are larger than other Palinuridae species (Groeneveld *et al.*, 2013). They hatch at a more advanced stage compared to *Jasus* and *Panulirus* species termed the Phyllosoma. Phyllosomas of *Palinurus elephas* are unique in their morphology and their life history. The 1st instar is around 2.8 mm long compared to 1.6-2 mm of *Palinurus japonicus*. The hatched Phyllosomas are similar in size to the 3rd instar of *Palinurus japonicus*. Heavy mortality (50-80%) occurred in the 1st instar larval stage in laboratory culture (Kittaka, 1997). In phyllosoma culture, long pereopods were often injured. Lost pereopods regrew at the following moult but regenerated ones were usually fragile and often lost, leading to a decrease in feeding activity. The exopods of the 3rd pereopods are already elongated though still incomplete in the 1st instar of *Palinurus*.

Phyllosomas drift offshore during a long pelagic life and return inshore after many moults to metamorphose and settle in the puerulus stage. The phyllosoma larval stage was reported to be 5-6 months in the Mediterranean and 10-12 months in the Atlantic Ocean (Mercer, 1973). In culture, phyllosomas of *Palinurus elephas* metamorphosed into pueruli after 132-148 days, a short lifespan compared to 200-300 days in other species of spiny lobster. Lowering the water temperature of the cultures from 18-20°C to 15-17°C and feeding different types of bivalves did not bring any improvement to survival. Jellyfish were their preferred food (Kittaka, 1997). The advanced development at hatching and shorter phyllosoma development meant that *Palinurus elephas* was thought to be the preferred species for aquaculture. However, survival has been poor for the species in more than 10 years of the culture trials (Kittaka, 1997).

Settlement period

The pueruli (intermediate juvenile-larvae stage) settled between June and July in the western Mediterranean (Diaz *et al.*, 2001). Temperature is a critical factor affecting settlement success (Diaz *et al.*, 2001) with larvae settling in warmer months of both the Mediterranean and the Atlantic. Larvae prefer to settle at depths of between 10-15 m.

Population dynamics

Fishing techniques have changed from the use of pots and diving to trammel nets. These techniques are more efficient and caused a particular decline in population in the Atlantic Ocean (Goñi & Latrouite, 2005). *Palinurus elephas* species is generally targeted at depths between 50-150 m (Catanese *et al.*, 2018). In order to buffer the impact on recruitment from overfishing, it is important to maintain populations with a broad range of age and size classes (Diaz *et al.*, 2016). The species are also sensitive to displacement due to their lack of capacity to 'home' and relocate to their place of origin (Follesa *et al.*, 2014).

Palinurus elephas is considered to be by-catch of some 100 finfish fisheries. The genera *Homarus*, *Cancer*, *Palinurus* and *Necora* can all be caught using the same traps (Tully *et al.*, 2003). The use of closed season management appears to be the most effective currently (IUCN, 2018). Landings of

Palinurus elephas have fallen since 1997 from 42 million tonnes (mt) in that year through 19 mt in 1998 to 15 mt in 1999, 2000, 2001 and 2002 (FAO, 2002). The Welsh pot-hauled crawfish fishery fell from 55,000 kg in 1979 to less than 500kg in 1995 (Hunter, 1999). According to the Dublin Marine Institute, overfishing via tangle nets during the 1970's is thought to have been the main cause of the stock collapse. The significance of this decline is highlighted in Davies(2016) who found, during his diving expeditions in the 1960's, that each time a crawfish was removed from a hole a new crawfish moved into the same hole. In St. Ives 64 crawfish were found in a single dive in the same decade and the best sighting by Davies' three man crew was 410 crawfish during a south Wales dive.

Numbers in the Mediterranean have also been reduced (Campillo & Amadei, 1978). Reasons for the decline are also thought to be due to the use of more efficient capture mechanisms as seen in the Atlantic. Environmental conditions may also play an important role (Hiscock, pers. comm., based on observations in Russell, 1973 and Wilson, 1951).

Despite these declines, 215 individuals have been recorded around the south of England to Pembrokeshire and Jersey (SWME, 2016) since 2014. There was a range of sizes, from large to small including two juveniles. This suggested a potential for recruitment and recovery of the population (Jones, 2011). Higher numbers were also seen all around Cornwall, particularly Falmouth bay (Slater, 2017). Whilst numbers fluctuated over the years, there was a low number of individuals until 2015 where there was a dramatic increase in crawfish sightings in southern England; up to 25 individuals in 2015. Many of these individuals were juvenile which means there is a potential for this growth to be sustained (Slater, 2015).

Data from the Isles of Scilly (2014) tagging programme showed most recaptured individuals were male. Many of the recaptured males and females showed no growth after 100 days. This suggests a bias towards a male population around the Isles of Scilly. The low numbers of juveniles recaptured is also a cause for concern as it suggests a low recruitment (IFCA, 2015).

Although the larvae have a potentially large dispersal range, genetic differentiation has been reported between the populations from Brittany and UK as well as between the Atlantic and Mediterranean populations has been reported (Palero *et al.*, 2011; Babbucci *et al.*, 2010). This difference is due to a limited gene flow and suggests a restricted larval dispersal. The restriction is most likely caused by oceanographic factors such as the Gulf Stream and oceanic processes (e.g. currents) from the Atlantic Ocean. In addition, there is a limited exchange between the east and west Mediterranean populations. In the north-west Mediterranean basin, there is a mesoscale cyclonic gyre caused by the northern Balearic currents. This gyre may lead to larval retention with the particular area and, hence, population subdivision.

Sensitivity review

Resilience and recovery rates

Palinurus elephas is intolerant of removal by fisheries or any predation by other species (especially likely for juveniles) that might occur. Recovery at a location may be by migration, however, evidence has shown a lack of long distance travelled by the species once settled from the larval stage (see migration). Recovery after a loss will, therefore, most likely be from larval settlement, which (see 'Population dynamics' above) may be episodic with decadal gaps between significant recruitment events. This species grows relatively slowly compared to other crawfish and has a long life expectancy of around 25 years (Marin, 1978).

The species appears to have a strong circadian rhythm and therefore remains in their shelters for a majority of the day. This ability to seek out and remain in shelters for long periods of time allows the crawfish to protect itself from both fishing equipment and predators. *Palinurus elephas* are also able to survive up to a week with no food during their pre-moult stage. Therefore, they are able to remain in their shelters for long periods of time and avoid fishing or natural events such as storms. *Palinurus elephas* are opportunistic feeders. This means they have the ability to adapt their diet if a certain prey species becomes unavailable. Shelters also provide a refuge for newly settled larvae, allowing recruitment.

Palinurus elephas reproduces annually and the eggs are incubated by the female. Despite this, the fecundity of the species is three to five times lower than other species in the same genus (Hunter, pers. comm.). *Palinurus elephas* is most vulnerable to the impacts of stress during breeding. This means the species has to weigh up the potential detrimental cost against the potential for recruitment (Ansell & Robb, 1977). An increase in stress caused directly and indirectly by humans such as fishing and climate change may reduce survival rates of females during the breeding period.

In culture experiments, single males bred with multiple females (Kittaka, 1997). The selected male also needed to be of a similar size to the female to fertilise successfully. A reduction in both the number of males as well as the range in male sizes could cause a reduction in available, suited, males for mating. The reduction of males may also put pressure on the remaining males in the population to produce enough sperm, again limiting overall reproduction and therefore fecundity (Mouat & Shelmerdine, 2012).

Palinurus elephas females of 10.5-11 cm CL in size contribute the most to egg production of a population. Larger females produce, on average, five times more eggs and larger larvae compared to smaller females (Goñi et al. 2003). In contrast, reduced male size has not been shown to affect their mating success.

The larvae of *Palinurus elephas* hatches at a far more advanced and developed state compared to *Jasus* and *Panulirus*. Despite this, observations and attempts at culturing the phyllosomas are yet to be successful. In culture, the 1st instars suffered heavy mortality (50-80%), (Kittaka, 1997).

The long pelagic life of the larval stages increases the potential range for dispersal but also increases their vulnerability to predation and physical damage and, hence, potential mortality and reduced recruitment. Larvae also need to travel in a direction that takes them close to suitable habitats for settlement. Once near a suitable general location, larvae may use olfactory or auditory clues to find a final location to settle (see, for instance, Stanley et al., 2012). Evidence of population

subdivisions between and within Atlantic and Mediterranean populations suggests that larval survival and recruitment are not as effective as their long pelagic life and advanced stage of development might suggest.

Following the major decline in numbers and reduced distributional occurrence in *Palinurus elephas* in parts of south-west Britain at least since the 1970s (see 'Population dynamics') the remarkable recovery that has occurred since about 2014 demonstrates the severity of the over-fishing that caused the decline and, most importantly, the long time before any potential for recovery. Small individuals were seen at Lundy and at Skomer in 2007, although no such individuals were observed in over 20 years previously (Hiscock *et al.*, 2011). The recruitment that has occurred since 2014 (SWME, 2016) is large and suggests that *Palinurus elephas* has the ability to recover from local extinction or severe reduction in numbers. However, this recovery appears to be very slow and it has been approximately 40+ years since a recruitment of this scale has been reported (Hiscock *et al.*, 2011).

Marine Protected Areas may also aid recovery. After eight years of reduced fishing pressure, the catch rates within the Columbretes Islands, Spain, reserve were much higher and had significantly increased after a six month closed season. Despite the lack of exact numbers, the population has shown the ability to recover with the reduction of fishing pressures (Goñi *et al.* 2001). Diaz *et al.* (2016) suggested that it is important to maintain populations with a broad range of age and size classes, in order to buffer the impact on recruitment from overfishing.

There has been a lack of recovery of *Palinurus elephas* for ca 30 years after the decline in populations due to overfishing. Hiscock *et al.* (2011) suggested that recruitment from the plankton was episodic and infrequent. The evidence of genetic subdivision (Palero *et al.*, 2011; Babbucci *et al.*, 2010) supports this view. The Recovery is also hindered by the low fecundity, slow growth rate, and limited section of the population (large females) reproducing (Mouat & Shelmerdine, 2012). In addition, adults are nocturnal and favour specific shelters so that mobility is limited and individuals from other populations are unlikely to repopulating areas from which the species is removed.

Resilience assessment. Recruitment to and recovery of populations is likely to be prolonged and/or episodic. Therefore, recovery from any loss of the population (i.e. a reduction in the extent or abundance, resistance is 'Medium' or 'Low') may take up to 25 years where the populations are sparsely distributed (e.g. in Britain). Hence, a resilience of '**Low**' will be recorded. However, where the population is severely reduced in abundance or extent (i.e. resistance is 'None') a resilience of '**Very low**' will be recorded.

Hydrological Pressures

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

Palinurus elephas is found in temperate (North Sea) to warmer waters as far south as the western basin of the Mediterranean. Different populations may have different thermoregulatory and adaptive ability, due to a lack of overlap and gene flow between populations (Palero *et al.*, 2011, Babbucci *et al.*, 2010). Summer catches in Scotland were higher than winter catches (Ansell & Robb, 1977). This was due to the higher occurrence in shallower waters during periods of summer temperatures. An increase in temperature might encourage individuals to move into the warmer areas, based on summer migratory inshore activity, which would increase vulnerability to inshore

catches.

Larval settlement takes place within a very limited thermal window, centred around the warmest months in both the Mediterranean and Atlantic (Diaz *et al.*, 2001). Settlement begins when the sea surface temperature increases mid-May and peaks in June-July. This is a relatively short settlement period. Increased temperatures could decrease the time taken to settle, reducing gene flow further. Mercer (1973) suggested that egg loss was positively correlated with an increase in temperature due to an apparent increase in stress on the berried female. Egg loss during incubation by the females was around 26-28 % in the Western Mediterranean, higher than the Atlantic Ocean (Goni *et al.*, 2003). Acute temperature change in the Laboratory of the Marine Research and Aquaculture (LIMIA, Balearic Islands Government) saw temperatures rise to above 24°C which resulted in the mass mortality of *Palinurus elephas* (Mallol *et al.*, 2014) suggesting a low resistance to a sudden increase in temperatures. Sea surface temperature around the UK is projected to increase between 1.5-4°C by 2098 (Goodwin *et al.*, 2012). A study site in Ireland exposed to an increase of 0.3-0.5°C between 1950 and 2009 showed a substantial decline in abundance of *Palinurus elephas* (Goodwin *et al.*, 2012). However, this decline could have been due to an increase in fishing pressure.

Sensitivity assessment. The distribution of *Palinurus elephas* from Scotland to the Mediterranean suggests it would be resistant to a long-term change of 2°C in UK waters. It might increase in abundance in the northern UK (Hiscock *et al.*, 2001). However, an increase in temperature may reduce egg production and larval recruitment. Furthermore, a short-term, acute, temperature change may also result in adult mortality, although wild adults might be expected to avoid thermal effluents. This suggests a resistance score of '**Low**' with 'Medium' confidence. The resilience of the species is probably '**Low**' and sensitivity is assessed as '**High**'.

Temperature decrease (local)

Medium

Low

Medium

Q: Medium A: Medium C: Medium

Q: Medium A: Medium C: Medium

Q: Medium A: Medium C: Medium

Decreases in temperature may result in a reduction of population distribution in the British Isles. Crisp (1964a) reported that *Palinurus elephas* (studied as *Palinurus vulgaris*) held in the aquarium of the Marine Biological Station on the Isle of Man died during the severe winter of 1962-63. The water in the aquarium was supplied directly from Port Erin Bay and dropped to 3.5°C (the coldest since records began 60 years previously). In culture, lowering the water temperature of the cultures from 18-20 to 15-17°C did not affect the survival of the *Palinurus elephas* phyllosomas (Kittaka *et al.*, 2001).

Sensitivity assessment. Therefore, an acute change in temperature (a reduction in temperature of 5°C for 1 month), may result in local mortality, although in the wild adults might be expected to avoid thermal effluents or migrate to deeper waters. Hence, a resistance of '**Medium**' is suggested. The resilience of the species is probably '**Low**' and sensitivity is assessed as '**Medium**'.

Salinity increase (local)

No evidence (NEv)

Not relevant (NR)

No evidence (NEv)

Q: NR A: NR C: NR

Q: NR A: NR C: NR

Q: NR A: NR C: NR

Palinurus elephas inhabits oceanic waters at 35 ppt salinity. It is unlikely to be subjected to further increases in salinity, except due to localised hypersaline effluents. Adults might be expected to avoid such effluents. However, there is '**No evidence**' on which to base an assessment.

Salinity decrease (local) **Medium** **Low** **Medium**
 Q: **Low** A: **NR** C: **NR** Q: **Medium** A: **Medium** C: **Medium** Q: **Low** A: **Low** C: **Low**

In the laboratory, *Palinurus elephas* survived direct transfer from seawater (38 ppt) to 27 ppt. The return to prior haemolymph osmolality took 24h. Direct transfer to lower salinities (20 ppt) resulted in mortality (Lucu *et al.*, 2000). However, gradual acclimation showed a tolerance to more extreme dilution at 20 ppt. (decrease of 2 ppt every two days) suggesting an acclimation ability to a steady decrease in salinity (Lucu *et al.*, 2000). *Palinurus elephas* were only kept for acclimation for two weeks so that long-term effects were unclear. In the wild, reduced salinity conditions would probably cause migration to areas of 'normal' salinity. This abnormal migration may interfere with feeding and reproduction. Individuals are only likely to be vulnerable during inshore migration for egg laying (see life history) as these are areas most likely to experience low salinity. *Palinurus elephas* is more vulnerable to stress during mating and egg production (Ansell & Robb, 1977).

Sensitivity assessment. Therefore, the resistance of *Palinurus elephas* to a decrease in one MNCR salinity ('full' to 'reduced') category is recorded as '**Medium**' but with 'Low' confidence. The resilience of the species is probably '**Low**' and sensitivity is assessed as '**Medium**'.

Water flow (tidal current) changes (local) **Not relevant (NR)** **Not relevant (NR)** **Not sensitive**
 Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR**

Palinurus elephas has been found in habitats with water flows ranging from very weak to very strong (JNCC, 1999). Most populations are found in regions dominated by strong ocean currents or gyres (Groeneveld *et al.*, 2013). It is not likely to inhabit sedimentary areas, although it can forage in them. They are likely to prefer areas of good water flow or wave mediated flow, as both can keep the area clear of sediment. Therefore, an increase in water flow at the benchmark level is probably 'not relevant' as the species occurs in areas of strong flow. A significant decrease, in the absence of wave action, could result in siltation, smothering and change in the habitat, from which it would have to move/relocate. However, a change at the benchmark level (0.1-0.2 m/s) is probably not relevant in strong flow (>1.5 m/s). Therefore, this species is probably '**Not Sensitive**' at the benchmark level.

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

Palinurus elephas is found sublittoral and so will not be affected by a change in emergence. '**Not relevant**' is recorded. However, it should be noted that *Palinurus elephas* are stored alive out-of-water for up to two days for marketing.

Wave exposure changes (local) **Not relevant (NR)** **Not relevant (NR)** **Not sensitive**
 Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR**

Palinurus elephas is recorded from wave exposed, rocky habitats. Therefore, a change in significant wave height of 3-5% is probably not significant in these habitats. Hence, sensitivity is assessed as '**Not sensitive**' at the benchmark level.

Chemical Pressures

Resistance

Resilience

Sensitivity

Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
Not assessed			
Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
Not assessed			
Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
Not assessed			
Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR
No evidence			
Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
Not assessed			
De-oxygenation	Low Q: Low A: NR C: NR	Low Q: Medium A: Medium C: Medium	High Q: Low A: Low C: Low

Crustaceans were reported to be the most sensitive benthic organism to hypoxia based on a meta-analysis (Vaquer-Sunyer & Duarte, 2008). Most crustaceans would be lost (die) before the content of the water reached the threshold of 2 mg O₂/litre (Vaquer-Sunyer & Duarte, 2008). Ansell and Robb (1977) recorded *Palinurus elephas* as being not very tolerant to oxygen depletion, as a malfunction in tank circulation in their 800l aquarium resulted in immediate death for many individuals, although their work was based on a small sample size and the oxygen levels involved were not reported.

Sensitivity Assessment. The available evidence suggests that most crustaceans have a low resistance to hypoxia. *Palinurus elephas* is a mobile species and may be able to avoid localised hypoxia, depending on the extent and duration of the affected area so that only a proportion of the population may be affected. Resistance is therefore assessed as 'Low' but with 'low' confidence. Resilience is probably 'Low' and sensitivity is assessed as 'High'.

Nutrient enrichment	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR
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Nutrient enrichment from pollution and other sources can lead to an increase in algal blooms. In turn, this can lead to periods of deoxygenation (see deoxygenation pressure). **No evidence** specific to this species was found.

Organic enrichment	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Organic enrichment can lead to nutrient enrichment and deoxygenation. Organic enrichment encourages the productivity of suspension and deposit feeding detritivores and allows species to colonize the affected area to take advantage of the enhanced food (see removal on non-target species). However, 'No evidence' specific to this species was found.

A Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None	Very Low	High
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

All marine benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is, therefore 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	Not relevant (NR)	Not relevant (NR)	Not sensitive
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Selection of appropriate substrata providing adequate shelter is key in determining survival, especially in post-settlement stage (Diaz *et al.*, 2011). There is a huge reliance on structured refuges such as crevices and caves (Gristina *et al.*, 2011) due to a lack of ability to create their own shelters. This can create a bottleneck for recruitment especially in areas of high predation from predators such as *Octopus vulgaris*. Sheltering is one of their main and most effective defence mechanisms (Buscaino *et al.*, 2011).

The abundance of recently settled *Palinurus elephas* was found up to 10x lower in metamorphic substratum areas compared adjacent 'optimal' limestone area (Diaz *et al.*, 2005). This is due to a preference for a softer sedimentary rock with more crevices. However, a change in hard substratum to soft is highly unlikely and the pressure is 'Not Relevant' at the benchmark level.

Physical change (to another sediment type)	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Palinurus elephas inhabits hard rock substratum. This benchmark only applies to sedimentary infauna. Therefore 'Not relevant' is recorded.

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This benchmark only applies to soft rock and sediment. Therefore 'Not relevant' is recorded.

Abrasion/disturbance of the surface of the substratum or seabed

Medium

Q: **Low** A: **NR** C: **NR**

Low

Q: **Medium** A: **Medium** C: **Medium**

Medium

Q: **Low** A: **Low** C: **Low**

Crawfish need their antennae to detect predators. Legs are also important for locomotion as returning to their shelter is a primary defence (Buscaino *et al.*, 2011). When threatened by an octopus in the open, *Palinurus elephas* attempt to escape by using tail flips, darting backwards away from the attacker (Buscaino *et al.*, 2011). *Palinurus elephas* has a tough exoskeleton. At the benchmark level, some damage may occur, for example, broken legs, but is unlikely to cause death in the majority of the population. The impact on the habitat by the global tangle net fishery was scored as very low risk (Tully *et al.*, 2003). Trammel nets have shown to harbour relatively little impact on the seabed compared to other fishing activities such as trawling. Discarded specimens of *Palinurus elephas* in the observed trammel nets were almost exclusively damaged individuals. However, the gear is designed so that, *Palinurus elephas* arrive at the merchant's premises alive (Quetglas *et al.*, 2004). Net fisheries can result in mortality depending on the length of time *Palinurus elephas* is left in the nets and the levels of damage through contact with the net. As the nets are not very selective, they can result in catches of undersized individuals. If nets are not cleared regularly, this can result in juvenile mortalities (Mouat & Shelmerdine, 2012).

There are potential localised physical effects of traps on sediment when hauling and/or deploying. Fragile benthic species may potentially be damaged during both deployment and hauling. Discarded pots, like nets, can ghost fish, catching both commercial and non-commercial species (European economic interest groups, 2014). Adult shelter in crevices and overhangs in the rocky substratum during the day. Therefore, they are likely to be protected from passing gears during the day but vulnerable at night when they are foraging. Abrasion that reduces the cover of turf-forming species may reduce the survival of juveniles.

Sensitivity assessment. As individuals tend to reside in shelters during the day, they are unlikely to be caught or damaged by fishing gear and receive protection from passing gears. However, the population may be vulnerable to abrasion at night. Similarly, the juvenile habitat may be damaged by abrasion. However, the portion of the population affected will depend on the time of day, season, and geology of the habitat. Therefore, a resistance of '**Medium**' has been suggested with 'Low' confidence. Resilience is probably '**Low**' and sensitivity is assessed as '**Medium**'.

Penetration or disturbance of the substratum subsurface

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Penetration is not relevant for hard substratum dwelling species. Therefore '**Not relevant**'.

Changes in suspended solids (water clarity)

Medium

Q: **Low** A: **NR** C: **NR**

Low

Q: **Medium** A: **Medium** C: **Medium**

Medium

Q: **Low** A: **Low** C: **Low**

An increase in the amount of suspended sediment is unlikely to affect *Palinurus elephas* directly. *Palinurus elephas* appear to select shelters with the principal purpose of reducing the risk of attack by minimising visual detection. They prefer dens on shaded, sub-vertical substratum. This not only avoids daylight but reduces siltation rate in their holes (Gristina *et al.*, 2009). However, over the course of the benchmark, and depending on local hydrographic conditions, siltation may occur on the rocky substratum on which this species prefers. An increase in the amount of fine particulates, although unlikely to significantly change the nature of the substratum over the benchmark period,

may alter the proportion of different prey items available to the crawfish. However, they can remain in their shelters with no feeding efforts for a week before their moult (Groeneveld *et al.*, 2013) and may be tolerant of periods of starvation.

Sensitivity assessment. Since *Palinurus elephas* are active omnivores and undergo periods of fasting, a change in suspended sediment is unlikely to reduce total ingestion over the benchmark period. Therefore resistance has been assessed as '**Medium**' with 'Low' confidence. The resilience is probably '**Low**' and sensitivity is assessed as '**Medium**'.

Smothering and siltation rate changes (light) **High** **Not relevant (NR)** **Not sensitive**
 Q: **Medium** A: **Medium** C: **Medium** Q: **Medium** A: **Medium** C: **Medium** Q: **Medium** A: **Medium** C: **Medium**

The species is quite large and mobile. Smothering by 5 cm of sediment is unlikely to adversely affect adult *Palinurus elephas*. *Palinurus elephas* appear to select shelters with the principal purpose of reducing the risk of attack by minimising visual detection. They prefer dens on shaded, sub-vertical substratum. This not only avoids daylight but reduces siltation rate changes in their holes (Gristina *et al.*, 2009). Crawfish vulnerability decreases significantly on vertical substrata. They prefer semi-circular dens enabling them to restrict the entrance and resist extraction.

A light deposition of sediment is unlikely to cause an adverse effect due to the position of the preferred shelter and size of the organism. Therefore, a resistance score of '**High**' has been suggested with 'Medium' confidence. Resilience is assessed as '**High**' and Sensitivity score suggests this species is '**Not sensitive**' to light deposition of sediment.

Smothering and siltation rate changes (heavy) **Low** **Low** **High**
 Q: **Low** A: **NR** C: **NR** Q: **Medium** A: **Medium** C: **Medium** Q: **Low** A: **Low** C: **Low**

A heavy deposition could lead to an obstruction of the shelter entrance reducing the ability of *Palinurus elephas* to enter to leave their crevice. The deposition could also cause an indirect effect on the crawfish by smothering potential prey. Therefore, resistance is assessed as '**Low**' for this benchmark within the affected area. However, confidence is 'Low'. The resilience of the species is probably '**Low**' and sensitivity is assessed as '**High**'.

Litter **Not Assessed (NA)** **Not assessed (NA)** **Not assessed (NA)**
 Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR**

'**Not assessed**'. However, it is noted that *Palinurus elephas* will use shipwrecks and other man-made substrata that have found its way to the seabed as shelter.

Electromagnetic changes **No evidence (NEv)** **No evidence (NEv)** **No evidence (NEv)**
 Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR** Q: **NR** A: **NR** C: **NR**

'**No evidence**'

Underwater noise changes **Medium** **High** **Low**
 Q: **Medium** A: **Medium** C: **Medium** Q: **Medium** A: **Medium** C: **Medium** Q: **Medium** A: **Medium** C: **Medium**

Female *Palinurus elephas* stridulate in order to attract males (see Reproduction). In controlled

laboratory conditions, female locomotive behaviour increased under playbacks of male “rasps” (Filiciotto *et al.*, 2014). The acoustic signals emitted by *Palinurus elephas* is within the range of ultrasonic frequencies (20-55 kHz), (Edmonds *et al.*, 2016). Noise disturbance may interfere with the production or reception of these mating signals. Specimens of males and female *Palinurus elephas* in the same laboratory were exposed to recordings of ‘boat’ noise (ca 75-125 dB) from a nearby harbour in Italy, frequented by a range of vessels. Signals and ‘rasps’ were emitted in ‘control’ conditions. It was suggested that these provide interaction with group members in this gregarious species (Filiciotto *et al.*, 2015). The rasps are acoustic emissions caused by tail whips that cause a movement of antennae. These can be used for anti-predatory behaviour. In the presence of an octopus, individually and in groups, more rasps could cover a wide range of ocean (Buscaino *et al.*, 2011(b)). Groups behaviours are thought to provide advantages due to shared shelter, defence and detection of predators (Filiciotto *et al.*, 2015).

In the laboratory, artificial noise caused a significant increase in locomotor behaviour, which could deplete their energy reserves. Artificial noise also resulted in a loss of group behaviours in favour of individual behaviours, which could increase their vulnerability to predation (Filiciotto *et al.*, 2014) or interfere with mating. In addition, noise changed haemolymphatic parameters (Filiciotto *et al.*, 2014). Haemolymphatic biochemistry is a bioindicator for stressful conditions and poor health in crustaceans (Filiciotto *et al.*, 2014). Artificial noise resulted in haemolymph parameters typical of stress and reduced immune response and increased risk of disease (Filiciotto *et al.*, 2014). After experiencing shipping noise in a tank HSP27 (heat shock protein no. 27) increased three fold and the levels of haemocytes decreased both reflecting a stress response (Celi *et al.*, 2015).

Sensitivity assessment. The noise treatments used in the above studies do not compare easily with the benchmark leave of pressure. However, the available evidence suggests that artificial noise from ‘boats’ in a harbour could interfere with, group behaviour, mating, and induce stress in *Palinurus elephas*, as in doing so increase their risk of predation and disease and reduce reproductive success. Therefore, resistance has been assessed as ‘**Medium**’ as a precaution but with ‘**Low**’ confidence as further study is required. Lack of evidence for a permanent effect of exposure to noise means the resilience is probably ‘**High**’. Hence, the sensitivity of this species to noise pollution is assessed as ‘**Low**’.

Introduction of light or shading

Medium

Q: **Low** A: **NR** C: **NR**

Low

Q: **Medium** A: **Medium** C: **Medium**

Medium

Q: **Medium** A: **Medium** C: **Medium**

Palinurus elephas are a nocturnal species and prefer crevices on a 90°, vertical, angle to reduce light entering the shelter. *Palinurus elephas* prey nocturnally and, therefore, rely on the lack of light to reduce detection and predation. The abundance of *Palinurus elephas* decreased significantly under a full moon suggesting a high sensitivity for light (Goñi *et al.*, 2001). Artificial light tends to mirror the moonlight (Groeneveld *et al.*, 2013).

There is a potential for artificial light placed on a habitat to interfere with the nocturnal feeding and movement activities leading to a suggested resistance score of ‘**Medium**’ but with ‘**Low**’ confidence. Resistance is probably ‘**Low**’ and sensitivity is ‘**Medium**’.

Barrier to species movement

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Not relevant (NR)

Q: **NR** A: **NR** C: **NR**

Increasing evidence is showing a reduction in population gene flow. The restriction is most likely caused by oceanographic factors such as the Gulf Stream and mesoscale processes from the Atlantic Ocean restricting the larval distribution (see life history). Despite being a mobile species, they do not move around a lot and are mostly sedentary and population subdivision results from lack of gene flow via larval dispersal.

This pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit the dispersal of larvae but larval dispersal is not considered under the pressure definition and benchmark. Therefore, this pressure is described as '**Not relevant**'.

Death or injury by collision

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant to seabed habitats and benthic species. NB. Collision by grounding vessels is addressed under 'surface abrasion'.

Visual disturbance

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Decapod crustaceans have compound eyes and, therefore, have quite good vision and are likely to respond to movement in order to avoid predators. However, it is unlikely that the species will be affected by visual disturbance at the benchmark level. Therefore '**Not relevant**'.

Biological Pressures

Resistance

Resilience

Sensitivity

Genetic modification & translocation of indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

Palinurus elephas is notoriously difficult to rear in aquaculture despite hatching at an advanced stage (see e.g. Kittaka & Ikegami, 1988) and attempts at culture have been unsuccessful. There is evidence for genetic differentiation between the populations from Brittany and UK as well as between the Atlantic and Mediterranean populations. This difference is due to a limited gene flow and suggests a restriction on larval dispersal. However, there is '**No evidence**' that the species has been translocated or genetically modified, although, individuals caught in western Scotland have been transferred to the St Abbs Marine Station for study (K. Hiscock, pers. comm.).

Introduction or spread of invasive non-indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

The red king crab has the potential to invade GB from the northern Atlantic, Norwegian coast. *Paralithodes camtschaticus* is a large, highly mobile, generalist predator. This invasive predator reduces biomass, especially in bivalves and barnacles. It also feeds on molluscs and echinoderms, same as *Palinurus elephas* (ICES, 2005). Like *Palinurus elephas*, it also has a twenty-year lifespan and

pelagic larvae.

Despite the potential impacts, *Paralithodes camtschaticus* has not yet been reported in the UK. Therefore, there is 'No evidence' currently on the effects of non-native species on *Palinurus elephas*.

Introduction of microbial pathogens

High

Q: Low A: NR C: NR

High

Q: Medium A: Medium C: Medium

Not sensitive

Q: Low A: Low C: Low

Palinurus elephas is susceptible to crustacean shell disease, which is characterized by brown spots that erode away the exoskeleton. These lesions are often found to contain chitinoclastic bacteria. In addition, Alderman (1973) recorded the presence of a fungus bearing septate mycelium. Mortality of this individual occurred after six weeks. The fungus was found to have entered the body via ingestion and suggests that fungal related diseases are able to infect crawfish and appear to be less treatable than bacterial infections (Alderman, 1973). A total of 198 bacterial strains were identified amongst nine caught individuals. Despite this, no mortality was recorded over a period of 34 days and the bacteria appeared to be concentrated in the areas of infection (Mancuso *et al.*, 2010). *Vibrio* infections can cause serious diseases in spiny lobsters. Few cases have been reported and these have been in fisheries (Shields, 2011). Peritrich and suctorian ciliates are often found on the external surface of embryos, which indicates mother is unhealthy, probably due to not feeding well (Shields, 2011). For both diseases, no mortality was recorded over the study period.

Sensitivity assessment. The presence of diseases in the population will result in reduced health and viability of a proportion of the population. However, no evidence of large-scale mortality was found so resistance is assessed as 'High'. Therefore, resilience is probably 'High' and sensitivity is assessed as 'Not sensitive'.

Removal of target species

None

Q: Medium A: Medium C: Medium

Very Low

Q: Medium A: Medium C: Medium

High

Q: Medium A: Medium C: Medium

Palinurus elephas is one of the most commercially important spiny lobster species in the Mediterranean and northeast Atlantic (Goñi, 2005). This species is taken both as a targeted species and as a by-catch from other fisheries. Intensive potting (creeling), diving and tangle or trammel netting for *Palinurus elephas* has contributed to a very substantial decline in population size since the 1970's. For instance, the Welsh pot-hauled crawfish fishery fell from 55,000 kg in 1979 to less than 500kg in 1995 (Hunter, 1999). It is also highly exploited in the Mediterranean where a commercial decline of 30-50% has been observed over the last 30 years (Gonulal, 2015).

During fishing, intermediate survival was high for undersized lobsters in nets and traps allowing a safe return. However, after seven days left in the nets or traps survival was reduced to 64% (Catanese *et al.*, 2018). Despite the effort for regulation and policing, boats may have up to 10,000 m of trammel nets which they haul throughout the season and may leave to fish for three or more days (Goñi *et al.*, 2003).

The use of plastic traps usually results in little or no mortality of *Palinurus elephas*. However, when compared to collapsible traps, the mortality of *Palinurus elephas* in these traps was 1/3 of the total catch (Amengual-Ramis *et al.*, 2016). It has been suggested that mortality from fishing and due to bycatch is because of scavenging crustaceans and/or net damage. This emphasises the danger of leaving crustaceans including *Palinurus elephas* in fishing gear for long periods of time (Bord

lascaigh Mhara, 2011). In recent studies from the western Mediterranean, efforts have been made to introduce good practice for releasing undersized individuals in good condition (Franco, 2004).

Measures are in place to reduce the impact of fisheries. They include local bye-laws that prohibit the landing of berried lobsters and that set size limits for marketable lobsters (often 110 mm CL). Larger females produce five times more eggs and larger larvae (Goñi *et al.*, 2003) and exploitation usually targets larger individuals with newly mature females accounting for only 1 % of egg production.

Sensitivity assessment. Resistance is 'None' with 'Medium' confidence due to the increase in efficient fishery catching methods. The collapse of populations after over-fishing and the very long time taken for recovery in south-west Britain at least is a 'lesson' for recovery potential and resilience is 'Very Low'. This species is therefore predicted to have a 'High' sensitivity to removal.

Removal of non-target species

Medium

Low

High

Q: Medium A: Medium C: Medium

Q: Medium A: Medium C: Medium

Q: Medium A: Medium C: Medium

Palinurus elephas rely on structured refuges such as crevices and caves (Gristina *et al.*, 2011). Juveniles benefit from the burrows left by other species, e.g. in the Mediterranean the burrows in soft rock made by date mussels are an important habitat (Diaz *et al.*, 2001). This can create a bottleneck for recruitment especially in areas of high predation from octopus due to incomplete sheltering. Molluscs and sea urchins are the most important prey in their diet (Philips, 2013). This means a removal of these species could have an indirect effect on the survival of *Palinurus elephas*.

Palinurus elephas is considered to be by-catch of some 100 finfish fisheries. The genera *Homarus*, *Cancer*, *Palinurus* and *Necora* can all be caught using the same traps (Tully *et al.*, 2003). In Wales, in 2003, 65% of crawfish landed were caught as a result of bycatch from lobster fisheries (Perry, 2015). In Scotland, *Palinurus elephas* are caught as a bycatch in the bottom-set tangle net fishery for monkfish (Chapman, 2006).

Moving from the use of pots to trammel nets has increased the vulnerability of *Palinurus elephas* as a bycatch species. This is because both trammel and tangling nets are more efficient in capturing different individuals due to a lack of selectivity. Therefore, many species of different sizes are caught including *Palinurus elephas* even if it is not the target species (Trindade-Gonçalves, 2010). An investigation into what happens to the individuals caught via by-catch has shown that 75% of *Palinurus elephas* caught were sold despite not being targeted (Batista *et al.*, 2009). This means that *Palinurus elephas* is not only vulnerable to target fishing but also has the potential to be caught alongside other fish species in nets and crustaceans in pots.

Sensitivity assessment. Resistance to the removal of non-target species is 'Low' due to the potential reduction in prey and the vulnerability of *Palinurus elephas* to be caught as by-catch. Resilience is probably 'Low' and sensitivity is therefore assessed as 'High'.

Importance review

🔗 Policy/legislation

UK Biodiversity Action Plan Priority	☑
Species of principal importance (England)	☑
Species of principal importance (Wales)	☑
Features of Conservation Importance (England & Wales)	☑
Priority Marine Features (Scotland)	☑

★ Status

National (GB) importance	Not rare/scarce	Global red list (IUCN) category	Vulnerable (VU)
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🏠 Non-native

Native	Native		
Origin	Not relevant	Date Arrived	-

🏛️ Importance information

Importance Information

Palinurus elephas is the most valued large decapod throughout its range, potentially due to it being more accessible compared to other species, such as *Palinurus mauritanicus* (Babbucci *et al.*, 2010). It has a high unit value of (40-120 €/Kg). High levels of fishing have reduced the genetic diversity of the populations (Tufto & Hindar, 2003). In the North East Atlantic, it is a by-catch species where fishing has depleted its populations (Latrouite & Noel, 1997, cited in Goñi *et al.*, 2003).

There are peripheral fisheries off the south and west coasts of England, Wales, Scotland, and Ireland. Landings from Scotland in 1998 amounted to 15.8 metric tonnes, mostly from the southwest around Barra and South Uist. A considerable fishery existed off the Cornish coast in the 1970's but the population was over-exploited and nowadays exists at a much lower intensity. Total landings of *Palinurus elephas* in France have seen a downward trend with landings at 137, 128, 112, 104, 90, 44, 58, 59, 65 and 46 mt for the years 1993-2002 although again, no indication of effort is given. Declines in number are documented for crawfish fisheries elsewhere along the European Atlantic coast e.g. Ireland, Spain and Portugal. (Lock, 2011).

The collapse of populations in south-west Britain because of overfishing in the late 1960s and through the 1970s at least, was not reversed until about 2014 when large settlements and increasing populations of young crawfish were widely reported. This long period before apparent recovery is seen as a 'lesson' that recovery of over-exploited populations can take a long time and that such fisheries need to be well-managed (K. Hiscock, pers. comm.)

Protection

No fishing quotas are currently applied. In most fishing areas, fishing decreases or ceases during the breeding period. It is not permitted to catch berried females and the mesh size of the nets on fishing boats must be regulated (Quetglas *et al.*, 2004). Non-quota species, such as *Palinurus elephas*,

are more likely to be fished by inshore vessels. This means they are subject to less monitoring control and surveillance (Jones, 2011).

Palinurus elephas is considered to be bycatch of some 100 finfish fisheries. By-catch risk for this fishery has been assessed as a moderate risk (Quetglas *et al.*, 2004). Mitigating measures are in place in vessels > 12 m. Habitat impact of the tangle net fishery has been scored as very low risk (Quetglas *et al.*, 2004). Trammel nets have shown to harbour relatively little impact on the seabed compared to other fishing activities such as trawling. Anchoring of the nets has minimal impact on the sea floor. Despite this, they have the potential to be lost in bad weather, such as storms, and become ghost nets. In order to buffer the impact on recruitment from overfishing it is important to maintain populations with a broad range of age and size classes (Diaz *et al.*, 2016) (see population dynamics). Reintroduction of males and females in unfished areas, around Britain, may help to increase reproductive stock (Hiscock *et al.*, 2011) but, subsequent to that conclusion, recovery has occurred without intervention. The closed season management measure appears to be the most effective currently (IUCN, 2018). This entails a ban on fishing during the months of May-August in countries such as Spain and Portugal to protect the species during their more vulnerable period of mating. Crustacean fisheries in Greece have a closed season of four months, generally from September to December. There is also a ban on the capture of berried females Minimum landing sizes; 110 cm CL; Ireland, England, Wales and Scotland. 9.5 cm in France, 8.5 in Greece and 8 cm in Spain and Italy (Tully *et al.*, 2003).

Goñi *et al.* (2001) studied a population of *Palinurus elephas* that had been afforded protection by the Columbretes Islands Marine Reserve (Mediterranean) for eight years. They reported that catch rates in the reserve were conspicuously higher than at two unprotected sites. Furthermore, catch rates at one of the fished areas increased significantly after a six-month closed season. The fishery that has developed at the boundaries of the reserves suggests that spill over takes place. In 2018 Seasearch, south and west Wales, has increased publicity of the crawfish in order to record sightings and increase management efforts. The Manacles Marine Conservation Zone (MCZ) in south Cornwall has listed *Palinurus elephas* as one of their key species of protection (Bolton, 2018).

Aquaculture

Palinurus elephas are, in theory, attractive for culture (Ceccaldi & Latrouite, 1994). However, *Palinurus elephas* is notoriously difficult to rear in the laboratory despite hatching at an advanced stage (see life history, Kittaka & Ikegami, 1988) and attempts at culture have been unsuccessful.

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