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Basking shark (*Cetorhinus maximus*)

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

Chloe Wilson, Catherine Wilding & Harvey Tyler-Walters

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Basking shark feeding near the surface.
Photographer: Andrew Pearson
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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	Chloe Wilson, Catherine Wilding & Harvey Tyler-Walters	**Refereed by**	This information is not refereed
Authority	(Gunnerus, 1765)		
Other common names	-	**Synonyms**	-

Summary

Description

The basking shark is the largest fish in British waters growing up to a maximum of 12 m long, its size is the most obvious distinguishing feature. Smaller specimens can be identified by the stout body, moon-shaped tail and the five long gill slits that run from the back behind the head to round under the throat. The gill arches carry a high number of gill rakers that act as a filter to catch the plankton upon which the fish feeds. The basking shark is slate grey to black dorsally, lighter ventrally, with light patches under the snout and on the belly. Filtered water is expelled through the greatly enlarged gill slits. Basking sharks generally live in open waters but migrate towards the shore in summer, when they can be seen 'basking', i.e. swimming slowly at the surface with the mouth wide open with the snout and dorsal fin visible above water.

Recorded distribution in Britain and Ireland

Usually sighted in the summer in areas such as western Ireland, western Scotland, the Clyde, the central Irish Sea, approaches to the Bristol Channel and the western English Channel.

Global distribution

Circum-globally distributed in temperate to boreal seas (Sims, 2008) and sighted occasionally in the tropics (e.g. the Galapagos and Hawaii).

Habitat

Pelagic and migratory. Often observed feeding along tidal fronts on the continental shelf and shelf edge.

Depth range

0 - 1264 m

Identifying features

- Britain's largest fish, maximum length 10 - 12 m long.
- Dorsal surface grey to black in colour, undersides paler.
- Five long gill slits running from the back of the head to below the throat.
- Long snout, especially in juveniles.
- When feeding, characteristically cruises near the surface of the water with mouth gaping.

Additional information

Cetorhinus maximus live either solitarily or in shoals of up to approximately 400 individuals.

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Biology review

Taxonomy

Phylum	Chordata	Sea squirts, fish, reptiles, birds and mammals
Class	Elasmobranchii	Sharks, rays and skates
Order	Lamniformes	
Family	Cetorhinidae	
Genus	Cetorhinus	
Authority	(Gunnerus, 1765)	
Recent Synonyms	-	

Biology

Typical abundance	Low density
Male size range	10 - 12 m
Male size at maturity	5 - 7 m
Female size range	10 - 12 m
Female size at maturity	8.1 - 9.8 m
Growth form	Pisciform
Growth rate	0.4 m/year
Body flexibility	High (greater than 45 degrees)
Mobility	Mobile, Muscular contraction (body length), Swimmer
Characteristic feeding method	Searcher / forager, Swimming
Diet/food source	Heterotroph, Planktotroph
Typically feeds on	Calanoid copepods and other zooplankton.
Sociability	Gregarious
Environmental position	Pelagic, Water column
Dependency	No information found.
Supports	Host
Is the species harmful?	No

Biology information

Feeding

The basking shark (*Cetorhinus maximus*) is an obligate ram feeder, using its gill rakers to filter zooplankton from the water. In the UK, its preferred prey species are likely to include *Calanus helgolandicus* (Speedie, 1999) and *Calanus finmarchicus* (Sims *et al*., 1997), although other species of calanoid crustacean may be preferred outside of the UK. The analysis of stomach contents has shown that, while copepods are the dominant prey species, fish eggs, fish larvae, cirripede and decapod larvae are also consumed (Matthews & Parker, 1950).

Parker & Boesman (1954) suggested that the basking shark would shed its gill-rakers during autumn and go through a period of winter hibernation, triggered by low prey abundance and the inability to derive enough energy for growth. However, arguments opposing this idea have been put forward by Sims (1999) and Sims *et al.* (2003). Current evidence suggests that the basking shark can utilize the low concentrations of zooplankton (down to ca 0.5-0.6 g m^{-3}) found outside summer months (Sims, 1999; Sims *et al.*, 2003). For example, a study on *Cetorhinus maximus* by Sims *et al.* (2003) recorded diving activity (down to between 750 and 1000 m) and long range movement during winter in some individuals, indicating that they do not remain motionless at the seabed. Therefore, it is likely that gill-raker shedding is not universal to all individuals and shedding and regrowth may happen asynchronously (Sims, 2008).

Prey detection

At small spatial scales, Sims & Quayle (1998) suggested that (as is the case with sea birds; Nevitt *et al.*, 1995) *Cetorhinus maximus* may use olfactory cues to detect dimethyl sulphide, which is released by phytoplankton when they are grazed on by zooplankton. Basking sharks may also use electroreception via their electrosensory pores (ampullae of Lorenzini) to detect the electrical signals given off by the muscle movement of prey (Sims & Quayle, 1998). The ampullae of Lorenzini are concentrated around the snout (Kempster & Collin, 2011) suggesting their use to detect zooplankton distribution. This is supported by the reduced swimming speed of the basking shark during feeding (Sims, 2000), which would allow the shark to detect small-scale changes in prey activity (Kempster & Collin, 2011) whilst reducing drag-induced energetic costs.

Over various spatial and temporal scales, an adult basking shark demonstrates foraging patterns known as ‘Lévy walks’. This is the best search strategy to enable foraging on patchily distributed prey, whereby the predator is effectively a probabilistic or 'blind' hunter (Sims *et al.*, 2008). The basking shark is also known to exhibit ‘yo-yo diving’ (diving from surface to depth repeatedly with little time at the top or bottom), which is an additional foraging strategy used more commonly in summer months when prey distribution is more patchy (Shepard *et al.*, 2006; Witt *et al.*, 2014).

Growth

Growth rates have been estimated at 0.4 m per year (Pauly, 1978; 2002), which is slower than initially assumed because some basking sharks lose their gill-rakers and cease feeding during the winter. However, some individuals show behaviour consistent with foraging during the winter (Sims *et al.*, 2003), so actual growth rates may be slightly higher than estimated by Pauly (1978; 2002) (see Sims, 2008 for review).

Sociability

The basking shark is solitary predominantly but aggregations of 6 - 12 sharks can occur in areas of dense zooplankton abundance (Speedie, 1999), and in rare circumstances, groups may contain hundreds of individuals (Skomal *et al.*, 2004). Aggregations of *Cetorhinus maximus* engaged in close-swimming courtship-like behaviour are associated with thermal fronts (Sims *et al.*, 2000a; Sims, 2008; Gore *et al.*, 2019).

Habitat preferences

Physiographic preferences	Open coast
Biological zone preferences	Oceanic, Pelagic
Substratum / habitat preferences	Not relevant

Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Not relevant
Salinity preferences	Full (30-40 psu)
Depth range	0 - 1264 m
Other preferences	None
Migration Pattern	

Habitat Information

Migration

Migration in the basking shark (*Cetorhinus maximus*) is not fully understood. However, a number of patterns have been identified. Firstly, the basking shark can travel large horizontal distances, such as across the Atlantic in extreme cases. For example, one tagged basking shark travelled a distance of 9,589 km, moving from the Isle of Man, UK to Newfoundland, Canada in 82 days (Gore *et al.*, 2008). In a study of *Cetorhinus maximus* by Skomal *et al.* (2009), similarly large distances (approx. 9000 km) were estimated for the tracks of sharks moving southwards in the western Atlantic from Cape Cod, Massachusetts as far south as the mouth of the Amazon river. Southward migration can be justified by the need for food after seasonal declines in zooplankton abundance in the North. However, long distance transequatorial migration (Skomal *et al.*, 2009) seems too energetically costly to be for feeding alone. It is thought that the stable environment of the tropics may provide the conditions required for reproduction (e.g. mating, gestation or nursing grounds).

In the UK, basking shark migration is relatively ambiguous but there is some evidence for a north to south seasonal migration in response to changing thermal conditions, with northerly movement in early summer and southerly movement later summer/autumn (Sims *et al.*, 2003; 2008). In the UK, the basking shark may also undertake a seasonal west to east migration.

Diving Behaviour

In addition to horizontal movements, the basking shark also exhibits vertical migrations to a range of depths. Evidence indicates that *Cetorhinus maximus* commonly dives to depths within the range of 80 to 500 m (Francis & Duffy, 2002; Gore *et al.*, 2008). The plasticity in diving patterns is thought to be a response to changes in prey abundance, although this has not been observed directly (Gore *et al.*, 2008; Sims, 2008). The deepest recorded dive to 1,264 m was achieved by an 8.0 m female during her migration across the Atlantic (Gore *et al.*, 2008). *Cetorhinus maximus* was also recorded at similar depths (up to 904 m) in New Zealand (Francis and Duffy, 2002) and the Bay of Biscay (between 750- 1000 m)(Sims *et al.*, 2003).

Vertical basking shark migrations have been correlated with environmental variables such as tidal phase, lunar cycle and time of day (Shepard *et al.*, 2006). In their study, the maximum depth reached was 192 m. Of all vertical movements, most studied are the diel vertical migrations (DVM) exhibited by the basking shark in response to the DVM of its zooplanktonic prey (Sims *et al.*, 2005; Shepard *et al.*, 2006; Witt *et al.*, 2014). Sims *et al.* (2005) found that the whether the sharks exhibited normal or reverse DVM depended on the water mass under study. In deep stratified water, sharks assumed normal DVM coinciding with the DVM of the zooplankton. In tidal fronts, sharks exhibited reverse DVM that reflected the movement of copepod prey to avoid their planktonic predators (e.g. chaetognaths).

Life history

Adult characteristics

Reproductive type	Gonochoristic (dioecious), Sexual
Reproductive frequency	< Biannual
Fecundity (number of eggs)	2-10
Generation time	21-50 years
Age at maturity	12-20 years
Season	Data deficient
Life span	21-100 years

Larval characteristics

Larval/propagule type	Not relevant
Larval/juvenile development	See additional information
Duration of larval stage	Not relevant
Larval dispersal potential	Not relevant
Larval settlement period	Not relevant

Life history information

Reproduction

Cetorhinus maximus bear live young (ovoviviparity) that hatch from eggs inside the uterus of the female (Matthews, 1950). Matthews (1950) and Compagno (1984) suggested that the young are nourished by the consumption of other eggs (oophagy or interuterine cannibalism) within the uterus, which explained the large number of eggs found in the single functioning ovary (Kunzlik, 1988). However, Ali *et al.* (2012) suggested that oophagy would not be possible due to the large size of the egg capsules and the planktonic feeding method of the basking shark. Attempts to estimate gestation (pregnancy) period have resulted in a broad time scale, from 1 - 3.5 years (Parker & Stott, 1965; Compagno, 1984; Pauly, 2002; Sims *et al.*, 2008, 2015), after which, about six pups are born (Sund, 1943). Young basking sharks are observed in the late summer, suggesting that they are born at this time. New-borns are between 1.5 and 2 m long at birth (Sund, 1943) and, after giving birth the females are thought to rest for 2-3 years before mating again. Only two pregnant females have ever been recorded in the literature (Sund, 1943; Ali *et al.*, 2012). The lack of observations of pregnant females led Sims *et al.* (1997) to suggest that pregnant females did not surface, and spent time in deep offshore waters. The generation time of *Cetorhinus maximus* is estimated at 34 years (Sims *et al.*, 2015).

Sexual maturity in males is attained at a size range between 4 - 7 m and about 12 - 16 years of age, and in females between 8.0 - 9.8 m at possibly 16 - 20 years of age (Compagno, 1984; 2002). However, Ali *et al.* (2012) reported a 6.9 m female basking shark (off the Syrian coast) believed to be at the beginning of gestation, which indicated that females might mature at smaller sizes in some cases.

Sexual segregation

Populations of the basking shark (*Cetorhinus maximus*) are often reported with male and female individuals occurring together, particularly in the summer (Mathews & Parker, 1950; Sims *et al.*, 2000). However, female basking sharks were more abundant than males from surface fisheries off Scotland (Watkins, 1958) and Japan (Anon., 2002), while males were more common in subsurface nets around Newfoundland (Lien & Fawcett, 1986). It was suggested that the basking shark exhibits sexual segregation in surface activity (Lien & Fawcett, 1986; Bloomfield & Solandt, 2008).

Fecundity

Fecundity is thought to be very low in *Cetorhinus maximus* even when compared with other large ovoviviparous sharks (Compago, 1984; Sims, 2005). The only observed basking shark birth was in Norway (in August 1936). The female basking shark was caught and gave birth to six pups whilst being towed (Sund, 1943). However, Ali *et al.* (2012) reported a second pregnant female with 34 egg cases, which suggests a higher fecundity, particularly since Ali *et al.* reported no sign of egg consumption by within the uterus (oophagy). Despite this, basking sharks born in any one year comprise less than 2.8% of the population in any given year (Sims, 2008).

Mating

Mating has not been observed and probably occurs in deep water (Mathews, 1950; Sims, 2008). Courtship-like behaviours have been observed where the species aggregates at the surface to feed, i.e. at frontal systems. Courtship-like behaviour includes close-following (one shark following another closely), nose-to-tail swimming, parallel swimming, echelon swimming (sharks stationed behind and to the side of another in front of them), stacking (swimming below or slightly below and behind another), close-swimming (swimming within a body length of each other), and breaching (the shark leaps completely or partly out of the water) (Sims, 2008; Gore *et al.*, 2019). These behaviours have been reported from feeding aggregations of basking sharks in the Western English Channel (Sims *et al.*, 2000a), West Cornwall (Speedie & Johnson, 2008); West coast of Scotland and the Inner Hebrides (Speedie *et al.*, 2009; Gore *et al.*, 2019) and the coast of Nova Scotia (Harvey-Clark, *et al.*, 1999). Hence, Sims (2008) suggested that food rich areas where the sharks aggregated provided the opportunity to initiate courtship and were potential important areas for the sharks to find mates as well as to feed. However, Gore *et al.* (2019) found no relationship between the sex or size of a shark and close-following and suggested that following behaviours were not related to gender. Abrasions typical of male behaviour in other shark species were found on both sexes of the basking shark and the abrasion of pectoral fins, typical of mating behaviour, were mainly on females. Also, there was no clear evidence that breaching was related to mating. They concluded that close-swimming behaviours were probably related to hydrodynamic advantage for feeding. Nevertheless, they stated that mature sharks possibly use feeding aggregations to initiate pre-courtship behaviour (Gore *et al.*, 2019).

Sensitivity review

Resilience and recovery rates

The basking shark (*Cetorhinus maximus*) is the third largest fish in the world and one of only three filter-feeding sharks. As a member of the Order: Lamniformes, the basking shark shares similar life history strategies with its relatives in this group. It has a slow growth rate, estimated at 0.4 m per year (Pauly, 1978; 2002), partially attributed to the periodic loss of gill-rakers in some individuals, although not the entire population (Sims *et al*., 2003). The basking shark is long-lived, with a predicted lifespan of 40 -50 years, however, evidence is lacking to support a confident estimate (Garcia *et al*., 2008; Sims *et al*., 2015). Slow maturation rates are seen in the basking shark. In males, sexual maturity is attained at a size range between 5 - 7 m that is thought to be at about 12 - 16 years of age, and in females between 8.1 - 9.8 m at possibly 16 - 20 years in age (Compagno, 1984). However, Ali *et al.* (2012) reported a 6.9 m female basking shark (off the Syrian coast) believed to be at the beginning of gestation, which indicated that females might mature at smaller sizes in some cases.

Cetorhinus maximus are thought to pair and mate in early summer (Matthews 1950, Sims *et al*., 2000) after which, the gestation (pregnancy) period is 1 - 3.5 years (Parker & Stott, 1965; Compagno, 1984; Pauly, 2002; Sims *et al*., 2008, 2015). The basking shark probably bears live young, hatched from eggs within the uterus of the females (ovoviviparity) (Matthews, 1950). The method used to nourish the young within the uterus is debated, with evidence both for (Matthews, 1950; Compagno, 1984; Kunzlik, 1988) and against (Ali *et al*., 2012) the consumption of additional eggs in the uterus by the young basking sharks (oophagy/ interuterine cannibalism). Only two accounts of pregnancy in the basking shark have been published (Sund, 1943; Ali *et al*., 2012). In the first, a caught female gave birth to six pups suggesting a low fecundity. However, the findings of Ali *et al.* (2012) suggest a slightly higher fecundity, as a female was found with 34 egg cases (not all fertilized) at the beginning of gestation with no sign of oophagy. After giving birth the females are thought to rest for 2 years before mating again (Parker & Stott, 1965; Pauly, 2002; Compagno, 1984). Evidence indicates that basking shark recruitment is low, with basking sharks born in any one year comprising less than 2.8% of the population (Sims, 2008), which is consistent with long maturation, slow growth rates and low fecundity of the basking shark.

Mating has not been observed and probably occurs in deep water (Mathews, 1950; Sims, 2008). Courtship-like behaviours have been observed where the species aggregates at the surface to feed, i.e. at frontal systems. Courtship-like behaviour includes close-following (one shark following another closely), nose-to-tail swimming, parallel swimming, echelon swimming (sharks stationed behind and to the side of another in front of them), stacking (swimming below or slightly below and behind another), close-swimming (swimming within a body length of each other), and breaching (the shark leaps completely or partly out of the water) (Sims, 2008; Gore *et al*., 2019). These behaviours have been reported from feeding aggregations of basking sharks in the Western English Channel (Sims *et al*., 2000a), West Cornwall (Speedie & Johnson, 2008); West coast of Scotland and the Inner Hebrides (Speedie *et al*., 2009; Gore *et al*., 2019) and the coast of Nova Scotia (Harvey-Clark, *et al*., 1999). Hence, Sims (2008) suggested that food rich areas where the sharks aggregated provided the opportunity to initiate courtship and were potential important areas for the sharks to find mates as well as to feed. However, Gore *et al.* (2019) found no relationship between the sex or size of a shark and close-following and suggested that following behaviours were not related to gender. Abrasions typical of male behaviour in other shark species were found on both sexes of basking shark and the abrasion of pectoral fins, typical of mating behaviour, were mainly on females. Also, there was no clear evidence that breaching was related to mating. They concluded that close-swimming behaviours were probably related to hydrodynamic advantage for feeding. Nevertheless, they stated that mature sharks possibly use feeding aggregations to initiate pre-courtship behaviour (Gore *et al.*, 2019).

Elasmobranchs are thought to be naturally resilient to some types of injury (Riley *et al.*, 2009; Chin *et al.*, 2015). For example, wounds several centimetres long were indictable within weeks or months in blacktip reef sharks (*Carcharhinus melanopterus*) and fresh bite wounds healed in 3-5 weeks (Chin *et al.*, 2015). Longer healing times were reported in grey nurse sharks (*Carcharias taruus*) where necrosis from hook injuries took over six months to heal. Healing rates were probably slower in cooler waters. Similarly, minor abrasions in white sharks (*Carcharodon carcharias*) in the cooler waters (ca 18-20°C) of the Guadalupe Islands were visible for several months but a large bite wound healed in about nine months (Domeier & Nasby-Lucas, 2007; Chin *et al.*, 2015). Riley *et al.* (2009) reported that a whale shark (*Rhincodon typus*) survived a harpoon. It was observed with a wooden harpoon through its body and its poor condition suggested internal injuries. However, it was observed 331 days later having lost the harpoon and with signs of healing. Another whale shark was observed with a decapitated dorsal fin over four years, although the long term effects on feeding and reproduction were unknown (Riley *et al.*, 2009). However, in the Canadian long-line fishery, hooking mortality varies between 10 and 31% in blue sharks (*Prionace glauca*), the shortfin mako (*Isurus oxyrhinus*) and porbeagle (*Lamna nasus*) but about half of hooked porbeagles and makos died during or after fishing mostly with 2 days after release (Campana *et al.*, 2016). Capture by fishing is probably more traumatic than injury alone. But they also noted that their study could not detect delayed mortality due to altered behaviour and feeding or altered reproductive success (Campana *et al.*, 2016). No evidence on healing rates in basking sharks was found. However, photo-identification and observational studies of basking sharks regularly record injuries, scars (including lamprey scars), notches in fins, propeller injuries, ship-strikes, and marks from nets or ropes (Speedie & Johnson, 2008; Speedie *et al.*, 2009; Solandt & Chassin, 2013; Gore *et al.*, 2016). These observations suggest that the basking shark can heal and recover from a range of injuries.

Cetorhinus maximus experienced dramatic population loss caused by fisheries that targeted the basking shark for its valuable liver oil and fins. Exploitation by fisheries began in the 1700s in Norwegian, Scottish and Irish waters, and ended in the mid-1800s after a decline in basking shark abundance. Within this time, landings were as high as 1000 individuals per year in Irish waters (ICES, 2016). The Norwegian fishery restarted in 1920, later to be joined by the Scottish (the 1940s) and the Irish (1947). The Norwegians dominated the market by taking between 1266 and 4266 basking sharks per year (from 1959 to 1980), compared with lower numbers in Scottish (total estimate of 970 individuals, from 1946 to1953) and Irish waters (average of 1475 individuals per year, from 1951 to 1955). Although the extent and scale of these fisheries were not well recorded, in the 51 years between 1946 and 1997, at least 105,730 sharks (mainly females) were likely to have been captured in the North East Atlantic (Sims, 2008) with peak landings (5266 metric tonnes) observed in 1979 (ICES, 2016). Most basking shark fisheries reported declines in landings before they closed down (Sims *et al.*, 2015). The North East Atlantic fisheries experienced a large decline in basking shark total catch, with a total of 3680 t in 1977 compared with 119 t in the year 2000, before regulations were put in place (ICES, 2016). Sims *et al.* (2015) stated that the overall result of fishery efforts was thought to have reduced the basking shark population to less than half of its original size over the previous three generations (>100 years).

Regulations were put in place to control the exploitation of *Cetorhinus maximus*. In 2001, Norway reduced its basking shark landing quota to zero tonnes (Sims *et al.*, 2015), and in 2006 ICES advised a zero total allowable catch (TAC), placing the basking shark on the Prohibited Species List. ICES also advised that by-catch should be minimized (ICES, 2016). In addition, EU legislation prohibits Union fishing vessels from fishing basking sharks in all waters under Article 13 of the Council Regulation 2016/72 (ICES, 2016). This ban continues, however, dead or dying incidentally caught basking sharks can be landed but must be reported. In the UK, the basking shark has been protected since 1998 by the Wildlife and Countryside Act, Schedule 5 (ICES, 2016)

It is not known whether the basking shark population has recovered since protective measures were initiated in 2001 (Sims, 2008). However, public sightings schemes have provided some insight into the progress of the population. The longest ongoing basking shark public sighting scheme was initiated by the Marine Conservation Society (UK) in 1987 (Bloomfield & Solandt, 2006; Solandt & Ricks, 2009; Solandt & Chassin, 2013). By 2008, there were a total of 24,013 UK sightings recorded under this initiative (Sims, 2008). The project highlights yearly trends in basking shark presence and individual length estimates per sighting provide information on growth patterns. In 2013, ca 3,000 basking shark individuals were recorded in over 1,000 sightings (Solandt & Chassin, 2013). A smaller public sightings scheme was established in Ireland (1993) to estimate the population of *Cetorhinus maximus* specifically in Irish waters. It reported a total of 425 individual basking sharks in one year of observation, encompassing all Irish coasts (Berrow & Heardman, 1994).

Additional UK *Cetorhinus maximus* population information is provided by Sims *et al.* (1997; 2008, unpublished data), in the form of basking sharks observed per unit time, which allows yearly comparisons of abundance within a small location (500 km^2). This data showed that the years 1998 and 1999 had fewer sightings (0.01 and 0.02 sharks per hour, /hr), than the years prior (1995–1997: 0.10–0.35 /hr), and following (2000: 0.30 /hr and 2001: 0.14 /hr). This trend in surface swimming *Cetorhinus maximus* was positively correlated with the zooplankton data within this time, with more basking sharks reported during periods of higher zooplankton abundance (Sims, 2008). Overall, the surveys have provided some evidence for an improvement in the UK basking shark population. For instance, the average length of the animals recorded have been increasing in some schemes (Sims *et al.*, 2015) and some have reported an increase in total abundance, but whether this is reflective of the basking shark population or an increase in public sightings efforts is unknown (Sims *et al.*, 2015).

Hoelzel *et al.* (2006) studied the genetic diversity of the global population of the basking shark. In the study, Hoelzel *et al.* (2006) investigated the nucleotide and haplotypic (a group of alleles of different genes that are inherited together) diversity of a control region of mitochondrial DNA (mtDNA). Samples were taken from the tissue of stranded or incidentally caught basking sharks from the western North Atlantic, eastern North Atlantic, Mediterranean Sea, Indian Ocean, and western Pacific. The results indicated both low nucleotide and haplotypic diversity, with only six identified haplotypes found across the samples. Hoelzel *et al.* (2006) estimated an effective population size of only 8,200 individuals. The low genetic variation observed in their samples was thought to be due to a bottleneck event in the Holocene epoch (within the last 11,500 years).

Resilience assessment. *Cetorhinus maximus* is a large, slow-growing, planktivorous shark, maturing at 12- 20 years of age depending on its sex. The generation time is presumed to be lengthy at 34 years (Sims *et al.*, 2015) and females are thought to produce litters of around six pups (Sund, 1943). Each of these characteristics suggests that the basking shark population would be very slow to recover from major population loss, similar to the decline already experienced due to fisheries. The basking shark fishery remains closed (ICES, 2016) due to significant declines in landings between the years 1992 and 2000. Evidence in the UK indicates some level of improvement in total abundance in some areas (based on public sighting schemes) of the North East Atlantic population after fishery closures. Unfortunately, no reliable estimate of population size before or after fishing effort exists, making it difficult to calculate the population loss or the rate of recovery. However, Sims (2008) suggested that recruitment in the basking shark was low compared to other shark species, as the number of basking sharks born in any one year comprised less than 2.8% of the population. The recovery of the basking shark population is likely to be slow.

Therefore, if the population were to suffer some mortality (that is 'Medium' resistance, <25% loss of population) then recovery may take up to 10 years and resilience is assessed as '**Medium**' (2-10 years). However, if a pressure resulted in significant loss of population ('Low' resistance, loss of 25-75% of the population) then recovery could take over 10 years and resilience is assessed as '**Low**'. Similarly, if the population suffered a severe loss (>75%) the resilience is likely to be '**Very low'** (>25 years). The resilience assessment is based on high-quality evidence that is directly applicable to the species assessed and in general agreement about the rates of recovery and the recent declines in the natural population. However, there is little direct evidence to suggest that recovery has occurred in the past and a lack of understanding of the population dynamics of the species. Therefore, a precautionary confidence of Low is suggested for the resilience assessment.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: High A: High C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: High C: Medium

In the eastern Atlantic, a tagged shark experienced a temperature range of 5.8 to 21°C but demonstrated an apparent preference for temperatures of 15-17.5°C with 72% of temperature recordings falling within this range (Skomal *et al*., 2009). Basking sharks in the western Atlantic were reported to make transequatorial migrations, entering the warm waters of the tropics and occupying mesopelagic depths (Skomal *et al*., 2009). Skomal *et al.* (2004) cited prior studies by Owen in which basking sharks were sighted at sea surface temperatures between 11 to 24°C in the Gulf of Maine, although peak densities occurred at 22-24°C (Owens, 1984 cited in Skomal *et al*., 2004). Skomal *et al.* (2004) also suggested that basking shark departed the waters of the Gulf of Maine in early October as mean daily waters temperatures dropped from 15.8°C to 12.7°C. Witt *et al.* (2016) noted that tagged basking sharks in the Sea of Hebrides also began to move south in October when the daily mean water temperatures were ca 13-14°C. The tagged sharks experienced a range of temperatures of ca 9-15°C throughout the year during the duration of the tags.

Sims (2008) suggested that the basking shark was tolerant of a wide range of temperatures ranging from 5.8 to 21°C. The species can tolerate rapid changes in temperature associated with depth, on dives through the thermocline in stratified summer waters (Sims *et al*., 2003). A shark in this study experienced temperature gradients of up to 15°C in dives from 20 m depths to 100 m depths, reaching a maximum depth of 180 m in water with a temperature of 1°C (Sims *et al*., 2003). However, one individual was found beached and moribund in waters of 24°C, suggesting the species usually avoids warmer waters (Sims, 2008).

Sensitivity assessment. Basking sharks are found in temperate and tropical waters and are exposed to rapid temperature fluctuations (vertical temperature gradients of up to 15°C over ca 100 m) associated with swimming in surface and deep waters (up to 1264 m) (Sims *et al*., 2003; Sims, 2008; Gore *et al*., 2008). Although they may avoid warm waters (ca 24°C) their mobility would allow them to avoid localised warming at the level of the benchmark. Therefore, resistance is assessed as '**High**'. Hence, resilience is also **High** (by default) and sensitivity is assessed as '**Not sensitive' at the benchmark level**.

Temperature decrease (local)	High Q: High A: High C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: High C: Medium

In the eastern Atlantic, a tagged shark experienced a temperature range of 5.8 to 21°C but demonstrated an apparent preference for temperatures of 15-17.5°C with 72% of temperature recordings falling within this range (Skomal *et al*., 2009). Basking sharks in the western Atlantic were reported to make transequatorial migrations, entering the warm waters of the tropics and occupying mesopelagic depths (Skomal *et al*., 2009). Skomal *et al*. (2004) cited prior studies by Owen in which basking sharks were sighted at sea surface temperatures between 11 to 24°C in the Gulf of Maine, although peak densities occurred at 22-24°C (Owens, 1984 cited in Skomal *et al*., 2004). Skomal *et al*. (2004) also suggested that basking shark departed the waters of the Gulf of Maine in early October as mean daily waters temperatures dropped from 15.8°C to 12.7°C. Witt *et al*. (2016) noted that tagged basking sharks in the Sea of Hebrides also began to move south in October when the daily mean water temperatures were ca 13-14°C. The tagged sharks experienced a range of temperatures of ca 9-15°C throughout the year during the duration of the tags.

Sims (2008) suggested that the basking shark was tolerant of a wide range of temperatures ranging from 5.8 to 21°C. The species can tolerate rapid changes in temperature associated with depth, on dives through the thermocline in stratified summer waters (Sims *et al*., 2003). A shark in this study experienced temperature gradients of up to 15°C in dives from 20 m depths to 100 m depths, reaching a maximum depth of 180 m in water with a temperature of 1°C (Sims *et al*., 2003). However, one individual was found beached and moribund in waters of 24°C, suggesting the species usually avoids warmer waters (Sims, 2008).

Sensitivity assessment. Basking sharks are found in temperate and tropical waters and are exposed to rapid temperature fluctuations (vertical temperature gradients of up to 15°C over ca 100 m) associated with swimming in surface and deep waters (up to 1264 m). Their mobility would allow them to avoid localised cooling at the level of the benchmark. Therefore, resistance is assessed as **High**. Hence, resilience is also **High** (by default) and sensitivity is assessed as '**Not sensitive' at the benchmark level.**

Salinity increase (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Sensitivity assessment. *Cetorhinus maximus* is a fully marine species. It has a broad geographic range suggesting that the basking shark is able to cope with varying salinity levels. Supporting evidence is provided by studies that correlated environmental variables with basking shark distribution and found that their distribution could not be predicted by salinity levels alone (Soldo *et al*., 2008; Lucifora *et al*., 2015). In the case of hypersaline conditions, it is likely that the highly mobile *Cetorhinus maximus* would move to an area of normal salinity. Therefore, resistance is assessed as **High**. Hence, resilience is also **High** (by default) and sensitivity is assessed as **Not sensitive**.

Salinity decrease (local)	High Q: High A: High C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: High C: Medium

The basking shark is a fully marine species. It has a broad geographic range suggesting that it can cope with varying salinity levels. Soldo *et al.* (2008) and Lucifora *et al.* (2015) demonstrated that basking shark distribution could not be predicted by salinity levels alone. In New Zealand, the species has been reported to enter the brackish Lake Ellesmere (Ryan, 1974; Dodgshun, 1980; Francis & Duffy, 2002). A single five metre basking shark was recorded in the lake (Ryan, 1974) and in September 1979, numerous basking sharks were found in the same lake, with a maximum of 21 sharks observed in one day (Dodgshun, 1980). Lake Ellesmere is known to exhibit variable salinity, both spatially and temporally. In 1979, at the time of the basking shark encounters, the salinity at the entrance of the lake was thought to be 18 ppt. The basking sharks were presumably attracted by the high concentrations of zooplankton within the lake (Francis & Duffy, 2002).

Sensitivity assessment. The salinity change at the benchmark level is a decrease in one MNCR salinity category. *Cetorhinus maximus* is normally exposed to full salinity (30-40 ppt) and a reduction to variable salinity (18-40) did not have a negative impact on the health of the basking shark, in Lake Ellesmere. Also, as a highly mobile species, *Cetorhinus maximus* would be able to move away from any localised changes in salinity if they were to reach intolerable levels. Therefore, resistance is assessed as '**High**'. Hence, resilience is also **High** (by default) and sensitivity is assessed as '**Not sensitive**'.

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

Cetorhinus maximus is highly mobile so can move to areas with favourable feeding conditions, and is unlikely to be affected by local changes in water flow. A study by Witt *et al.* (2014) indicated that basking sharks spent most time in areas of low to moderate tidal speeds (mean 0.3 m/s) but the standard deviation of this value was from 0.06 - 1.0 m/s, which suggested that they can cope with varying tidal speeds. Therefore, a localised change of 0.1-0.2 m/s is unlikely to be significant, and resistance is assessed as **High**. Hence, resilience is also **High** (by default) and sensitivity is recorded as **Not sensitive**.

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

Sensitivity assessment. Changes in emergence are not relevant to the pelagic *Cetorhinus maximus* which is restricted to the open ocean.

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

As a mobile pelagic shark, with the ability to dive to depths of up to 1264 m (Gore *et al.*, 2008), it is unlikely that the basking shark will be impacted by small-scale changes in near shore wave height. However, wave exposure caused by stormy weather may have an effect. There are very few records of basking shark sightings during stormy weather, partly because of the logistical difficulties involved, but also because the increased mixing of the water causes a breakdown of the coastal fronts, so zooplankton is more widely distributed, and not aggregated near the surface. Although there may be small energy losses resulting from reduced efficiency of feeding, it is likely that basking sharks can dive to greater depths to continue feeding. Sims *et al.* (2003) showed how basking sharks continue to forage in the winter when prey are concentrated at depth rather than at the surface. A similar behavioural change may occur in stormy weather.

During calm weather in the summer, the water column becomes stratified and dense aggregations of zooplankton form along coastal fronts. This may be beneficial to *Cetorhinus maximus* due to increased feeding efficiency on the highly concentrated plankton. Therefore, a decrease in wave action may be of benefit.

Sensitivity assessment. *Cetorhinus maximus* is likely to avoid storms by diving to a greater depth to feed. In addition, at the benchmark level, a change of 3-5% of significant wave height is only a small change and is unlikely to affect the basking shark, especially in the open ocean. Therefore, resistance is assessed as **High** and resilience is **High** (by default). Hence, sensitivity is assessed as **Not sensitive.**

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

No specific accounts of transition element or organo-metal contamination in *Cetorhinus maximus* have been found. However, Cadmium and Lead were detected in the tissue of six different shark species in the eastern Mediterranean, whilst a component of antifouling paints, Tributyltin (TBT), was detected in blue shark kidneys (Watts *et al.*, 2001). Though little is known about the impacts of these chemicals on the health of sharks, Watts *et al.* (2001) stated ‘they are likely to cause severe damage to basic biological functions’.

As a filter-feeder, *Cetorhinus maximus* is also vulnerable to the indirect consumption of toxic substances via contaminated prey (zooplankton) however; there are currently no accounts of this in the scientific literature.

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

There is little information available in the scientific literature about the impacts of Hydrocarbon and PAH contamination on the basking shark/ However PCBs along with MEHP (plasticizer) and DDTs (toxic chemicals that adsorb onto the surface of plastics) were found incorporated into incidentally caught basking shark tissue in the Channel of Sicily, in the south Mediterranean (Fossi *et al.*, 2014b). This study also found MEHP in *Euphausia kronii* (krill), samples; a prey species for the basking shark, which indicated that some component of the chemical ingestion was indirect.

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available. Little is known about the impact of synthetic compounds on *Cetorhinus maximus*. However, PCB was detected in basking shark tissue (Zitko *et al.*, 1972; Fossi *et al.*, 2014b). (See ‘Litter’ for more evidence of PCBs).

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found.

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed.**

De-oxygenation	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No information could be found on *Cetorhinus maximus* ability to tolerate hypoxia, but as the species is large and pelagic, it is unlikely to be able to tolerate low levels of oxygen. However, as a highly mobile species, *Cetorhinus maximus* would be able to move to an area with preferable oxygen levels. Therefore, resistance has been assessed as **High,** recovery is **High** (by default) and sensitivity is assessed as **Not Sensitive.**

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

No information on the effect of nutrient enrichment or algal blooms was found. However, basking sharks are known to utilise oceanographic fronts that host an abundant food source (zooplankton) supported by the diffusion of nutrients from cold mixed water to warmer water and the subsequent growth of phytoplankton (Sims, 2008). As *Cetorhinus maximus* feeds on zooplankton, an increase in phytoplankton may increase the available food supply, not only in fronts but in other areas of enhanced nutrients. However, hypoxia caused by eutrophication may cause the basking shark to move to a more desirable area if the nutrient load rapidly increases.

Sensitivity assessment. *Cetorhinus maximus* is unlikely to be negatively impacted by nutrient enrichment at the benchmark level as it will lead to an increase in the food source. However, if nutrient levels lead to toxic blooms or hypoxia the, the highly mobile basking shark is likely to move to a more desirable area. Therefore, resistance has been assessed as **High,** recovery is **High** (by default) and sensitivity is assessed as **Not Sensitive.**

Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No information was found on the specific effect of organic enrichment on *Cetorhinus maximus.* However, as a filter feeder, an increase in organic enrichment would likely affect the basking shark indirectly by influencing primary productivity and, therefore, prey abundance. Additionally, the potential for gill-raker clogging associated with increased suspended solids is low due to the method of filter-feeding used (cross-step filtration), which is thought to concentrate particles away from the gills using vortical flow to resuspend the particles that might otherwise clog the gill-rakers (Sanderson *et al.*, 2016). Therefore, resistance has been assessed as **High,** recovery is **High** (by default) and sensitivity is assessed as **Not Sensitive.**

Physical Pressures

	Resistance	Resilience	Sensitivity

Physical loss (to land or freshwater habitat)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Basking shark abundance is related to plankton abundance within shelf-sea and headland fronts (Sims & Quayle, 1998; Sims, 2008; Speedie *et al*., 2009). Important areas for basking sharks include migratory pathways, such as the Irish Sea and the Firth of Clyde (Sims *et al*., 2003; Solandt & Chassin, 2013), and locations associated with feeding activity such as oceanic fronts e.g. tidal fronts in the English Channel and the Ushant Front, Brittany (Sims *et al*., 2003) and other hotspots in the south and west of Cornwall and west coast of Scotland (Speedie & Johnson, 2008; Speedie *et al*., 2009; Solandt & Chassin, 2013). Sims (2008) suggested that food rich areas where the sharks aggregated provided the opportunity to initiate courtship and were potential important areas for the sharks to find mates as well as to feed. Mating has not been observed and probably occurs in deep water (Mathews, 1950; Sims, 2008). Courtship-like behaviour includes close-following (one shark following another closely), nose-to-tail swimming, parallel swimming, echelon swimming (sharks stationed behind and to the side of another in front of them), stacking (swimming below or slightly below and behind another), close-swimming (swimming within a body length of each other), and breaching (the shark leaps completely or partly out of the water) (Sims, 2008; Gore *et al*., 2019). These behaviours have been reported from feeding aggregations of basking sharks in the Western English Channel (Sims *et al*., 2000), west Cornwall (Speedie & Johnson, 2008); west coast of Scotland and the Inner Hebrides (Speedie *et al*., 2009; Gore *et al*., 2019) and the coast of Nova Scotia (Harvey-Clark, *et al*., 1999). However, Gore *et al.* (2019) found no relationship between the sex or size of a shark and close-following and suggested that 'following behaviours' were not related to gender. Abrasions typical of male behaviour in other shark species were found on both sexes of basking shark while the abrasion of pectoral fins, typical of mating behaviour, were mainly on females. Also, there was no clear evidence that breaching was related to mating. They concluded that close-swimming behaviours were probably related to hydrodynamic advantage for feeding. Nevertheless, they stated that mature sharks possibly use feeding aggregations to initiate pre-courtship behaviour (Gore *et al*., 2019).

Doherty *et al.* (2017a) reported that basking sharks undertook post-summer migrations along the western coast of the British Isles from the vicinity of the Faeroes south to North Africa (perhaps further) via continental shelf and oceanic waters (up to ca 1000 km) at depths of 50-200 m. Post-summer densities were greatest in the Celtic and Irish Seas, the west coast of Scotland, and continental shelf of the west coast of Ireland (Doherty *et al*., 2017a). Doherty et al. (2017a) also reported that some individuals returned to the summer hotspots where they were tagged off the west coast of Scotland and the Isle of Man. Similarly, Doherty *et al.* (2017b), noted that three (or 36) tagged individuals shown inter-annual fidelity, returning to their tagged locations off the west coast of Scotland within a year of tagging. It is theoretically possible that an obstruction due to an offshore wind farm, wave or tidal device arrays, mariculture infrastructure could prevent access to fronts in the vicinity of headlands, currently used by this species. It is also theoretically possible that major engineering projects (e.g. barrages) in coastal seas could change the local hydrography significantly so that the fronts do not persist or do not form. However, no direct evidence of either situation was found to support this supposition.

Sensitivity assessment. The basking shark has a broad geographic range and is capable of ocean migrations (Sims, 2008; Gore *et al*., 2008; Doherty *et al*., 2017a) so that any loss of food supply is likely to be temporary as the animals find other frontal systems to frequent or areas to feed (see ‘reduction in prey’ below). For example, the decline in the Achill Island shark fishery (west Ireland) between 1925 and 1975, correlated with a similar decline in copepod abundance (Sims & Reid, 2002; Sims, 2008; Speedie *et al*., 2009). Also, the Norwegian fishery saw an increase in basking shark numbers after 1958, which suggested that the shark distribution shifted north in the mid-1950s in search of prey (Sims, 2008). Therefore, while local ‘hotspots’ or aggregations may be lost, the animal itself may experience some energy-loss at most and is capable of relocating to other areas in search of food. Therefore, resistance is assessed as '**High**' and resilience as '**High**' (by default). Hence, sensitivity is assessed as **Not sensitive.**

Physical change (to another seabed type)	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus*, which is restricted to open water.

Physical change (to another sediment type)	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus*, which is restricted to open water.

Habitat structure changes - removal of substratum (extraction)	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus*, which is restricted to open water.

Abrasion/disturbance of the surface of the substratum or seabed	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus*, which is restricted to open water.

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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus*, which is restricted to open water.

Changes in suspended solids (water clarity)	High Q: Medium A: Medium C: Medium	High Q: High A: High C: High	Not sensitive Q: Medium A: Medium C: Medium

An increase in suspended solids may affect the basking shark in numerous ways. Firstly, turbid waters attenuate light more rapidly than clear waters, which may result in a reduction in zooplankton prey (see ‘Reduction in prey’). Basking sharks have been recorded in turbid regions. An individual was tracked in the vicinity of the Amazon river mouth for approximately one month (Skomal *et al.*, 2009). In addition, the basking shark has been known to penetrate estuaries in some cases (Knickle *et al.*, 2017). Turbid waters might be thought to pose a risk of gill-raker clogging. However, there were no reports in the literature of basking sharks suffering from this problem. In addition, Sanderson *et al.* (2016) presented a model that showed how the basking shark might avoid gill-raker clogging by a particular filter-feeding method (vortical cross- step filtration).

Sensitivity assessment. The turbidity change at the benchmark level is a change in one rank on the WFD scale for one year. As a highly mobile species, *Cetorhinus maximus* would be able to move away from any localised changes in turbidity if they were to reach intolerable levels. Energy losses may occur if the increase in turbidity occurs over a broad geographic range, as *Cetorhinus maximus* would be required to travel further to find food. Therefore, resistance is assessed as '**High**'. Hence, resilience is also '**High'** (by default) and sensitivity is assessed as '**Not sensitive'**.

Smothering and siltation rate changes (light)	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus* which is restricted to open water.

Smothering and siltation rate changes (heavy)	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

Changes to the seabed are not relevant to the pelagic *Cetorhinus maximus* which is restricted to open water.

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

A high abundance of marine plastics and microplastics has been reported in areas of basking shark activity. These include the north Atlantic, the North Sea and the Pelagos Sanctuary in the Mediterranean (a specific feeding area for the basking shark) where plastics are increasing (Thompson *et al.*, 2004; Fossi *et al.*, 2012; Panti *et al.*, 2015). In the Mediterranean, Fossi *et al.* (2014a) calculated that the basking shark (with a swimming speed of 0.85 m/s and mouth gape of 0.4 m^2) could theoretically ingest 13,110 microplastic items per day, which suggested a vulnerability to contamination by both microplastics and their associated contaminants. Fossi *et al.* (2014b) reported microplastic chemical consumption by basking sharks. They found MEHP (a plasticizer) along with PCBs and DDTs (adsorbed on the surface of plastics) incorporated into incidentally caught basking shark tissue in the Channel of Sicily, south Mediterranean. They also found MEHP in *Euphausia kronii* (krill) samples; a prey species for the basking shark, which indicated that some component of the plastic contaminant ingestion was indirect. However, no evidence of the effect of microplastic consumption or the contaminant burden on health or viability was found. Macroplastic litter such as discarded (ghost) fishing gear could be a major threat to the basking shark. The United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO) have estimated that at least 640,000 tonnes of fishing gear are left in our oceans each year (World Animal Protection, 2014). Stelfox *et al.* (2016) concluded that 'ghost fishing' (by discarded or lost fishing gear) could be a significant source of mortality in elasmobranchs but that there is a lack of data on direct effects.

Sensitivity assessment. Basking sharks are routinely observed with injuries and scars consistent with entanglement in ropes or nets (Darling & Keogh, 1994; Bloomfield & Solandt, 2006; Speedie *et al.*, 2009; Solandt & Chassin, 2013; Gore *et al.*, 2016) indicating that they can survive, and elasmobranchs are thought to be naturally resilient to some types of injury (Riley *et al.*, 2009; Chin *et al.*, 2015). However, while evidence of entanglement by set fishing gear exists (see 'Removal of non-target species') no direct evidence of the effect of 'ghost fishing' on basking sharks was found.

Similarly, while the evidence suggests that basking shark ingest microplastics and adsorbed contaminants, any adverse effect of the contaminant burden on the individual (if any) was not reported. Therefore, there is not enough evidence on which to base an assessment.

Electromagnetic changes	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Electromagnetic detection is well recorded in elasmobranch species and is thought to be a method of both prey detection and navigation (Kalmijn, 1971, 1982; Meyer *et al.*, 2005; Hart & Colin, 2015). The basking shark is thought to forage for zooplankton using passive electroreception, performed by the electrosensory pores focussed on its snout (Kempster & Collin, 2011). Zooplankton produce weak electric fields (up to 0.1V/m, Kempster & Collin, 2011). Sharks can detect voltage gradients of ca 5 nV/m and the biopotentials of prey (1-500 mV) at distances of up to 0.5 m (Hart & Collin, 2015). Therefore, if the basking shark is able to detect these signals, it is probable that it will also detect electric fields at the benchmark level of 1 V/m. However, little is known about the direct impact of changing electric fields on basking sharks. Gill & Kimber (2005) stated that electric fields may cause an attraction or avoidance response in some shark species. Kalmijn (1982) suggested that elasmobranchs (including *Mustelus canis* and *Prionace glauca*) were generally attracted to electric fields in the range 0.005 to 1 mV/cm and avoid those around 10 mV/cm, due to the field being perceived as prey or a threat depending on its intensity. In shark repellent tests, the effects of electromagnetic repellents were often species-specific (Hart & Collin, 2015).

Less is known about the detection of magnetic fields by the basking shark. Other sharks (*Carcharhinus plumbeus* and *Sphyrna lewini*) are attracted to magnetic fields in the range of 25-100 mT over <7 m (Meyer *et al.*, 2005). However, the magnetic field used in that study was far more intense than the benchmark level (10µT). Hart & Collin (2015) reported mixed results with the use of magnets on long-line and hook-line fisheries. For example, shark catch rate was not reduced by strong magnets (14,800 G; 1.4 T) but was significantly less than controls with weaker magnets (3,850 G; 0.38 T), and the repellent effect was species-specific. Hart & Collin (2015) concluded that further research was required in the use of electromagnetic fields as shark repellents.

Sensitivity assessment. There is little direct evidence of the impact of electromagnetic fields on the basking shark. However, if the behaviour of this species reflects that of other sharks (see above) it may be attracted or repelled by fields at different strengths. The basking shark can probably detect electric fields at the benchmark level (1V /m) and, if it reflects the behaviour of *Mustelus canis* and *Prionace glauca*, a field of this strength may elicit an avoidance response. There is no evidence to show the direct impact of a magnetic field of 10 µT on basking sharks. But magnetic fields have been shown to attract sharks and might, therefore, affect the behaviour of this species too. However, individuals may avoid or move away from localised areas of strong electric and magnetic fields and any temporary attractive or avoidance responses caused by fields at the benchmark level are likely to result in little more than small-scale energy loss. Therefore, resistance is assessed as '**High**'. Hence, resilience is also '**High**' (by default) and sensitivity is assessed as '**Not sensitive' at the benchmark level.**

Underwater noise changes	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Elasmobranchs have been shown to react to noise (Myrberg, 2001; Casper *et al.*, 2012; Hart & Collin, 2015). Casper *et al.* (2012) and Hart & Collin (2015) noted that elasmobranchs have a relatively narrow auditory range and poor sensitivity when compared to many teleosts, although they also noted that studies were limited to only a few of the hundred species of elasmobranches. Nelson & Gruber (1963) found that some sharks (including *Carcharhinus leucas*, *Sphyrna* sp., *Negaprion brevirostris* and *Galeocerdo cuvieri*) could be strongly attracted to rapidly and irregularly pulsed sounds (mirroring the vibrations caused by struggling prey) at below 60 Hz. Sudden loud noises of low frequency have been shown to elicit an avoidance response in most fish (Vella *et al.*, 2001). Similar findings by Myrberg *et al.* (1978) show avoidance behaviour in some sharks in response to rapidly changing sounds and sudden onset of transmission of an intense sound (impulsive sounds). Casper *et al.* (2012) noted that sharks were startled by sudden onset loud noise (20-30 dB above ambient) but habituated to the sound after a few trials. Casper *et al.* (2012) also suggested that noise from offshore wind farm operation and boats (shipping) were unlikely to cause hearing loss or damage in sharks, but that the noise of pile driving (that can reach ca 237 dB re 1 µPa at 100-1000 Hz) could cause a short-term decrease in hearing sensitivity. Barotrauma (due to the impulse energy caused by the hammer hitting the pile) was shown to damage the internal organs of teleost fish and suggested that the resultant vibration through the substratum might be a particular concern for demersal sharks and rays in contact with the substratum (Casper *et al.*, 2012). Hart & Collin (2015) reported that broad-band, low frequency biased, 'pink noise' was effective at repelling sharks, especially if suddenly or rapidly increased in loudness, and that a personal protection device claimed to repel sharks using pulsed sound in the range of 30-500 Hz or 200-1500 Hz. But they also noted that sharks rapidly habituate to both attractive and repulsive sounds (Hart & Collin, 2015).

Little information on sound detection in the basking shark was found. Basking sharks have been reported to dive and move away from the area if disturbed by boats (Bloomfield & Solandt, 2008) but have also been noted to be relatively unaware of surface vessels (Speedie & Johnson, 2008). Basking sharks killed by the prior harpoon fishery were shot at very close range and they generally show little reaction to being tagged. Speedie & Johnson (2008) note that slow-moving vessels elicit hardly any response when groups of basking shark are feeding. Wilson (2000; cited in Speedie & Johnson, 2008) noted that engine noise and angle of approach had a limited effect. However, in the Isle of Man, courtship-like behaviour appeared to be disturbed by an approaching motorised craft, at a range of 1 km (Bloomfield & Solandt, 2006). On the other hand, at Gwennap Head, Seawatch Southwest wildlife observers in 2007 began to see a change in behaviour when vessels came within 10 m of individual basking sharks. Observations from Gwennap Head by Seawatch Southwest wildlife observers in 2007 reported that the sharks only showed altered behaviour when vessels approached very close to them (within 10 m) (Bloomfield & Solandt, 2006). Darling & Keogh (1994) also suggested that basking sharks were attracted to vessel propellers.

Sensitivity assessment. There is no direct evidence of sound causing basking shark mortality or stress, however, the behaviour of other sharks can be altered by sound in the short-term. The response of basking shark to boats may be due to either their noise or visual disturbance (see 'Visual disturbance'). Hence, if sound at the benchmark level, elicited an attractive or avoidance response in the basking shark, it would be likely to experience some energy-loss at most due to short-term interruption in feeding. Therefore, *Cetorhinus maximus* is probably resistant to noise at the benchmark level so resistance is assessed as '**High'**. Hence, resilience is also '**High'** (by default) and sensitivity is assessed as '**Not sensitive' at the benchmark level**. However, the applicability of the behaviour seen in other shark species to *Cetorhinus maximus* needs further study, particularly considering its feeding strategy as a filter-feeder (no need to detect struggling prey), and the confidence in the assessment is 'Low'.

Introduction of light or shading	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

There are no reports of *Cetorhinus maximus* being disturbed by light pollution. In addition, they have very small eyes in proportion to their body (SharkTrust, 2010). Moreover, if temporarily disturbed by high light levels, *Cetorhinus maximus* is highly mobile and able to move towards more preferable conditions. Therefore, resistance is assessed as '**High'**. Hence, resilience is also '**High'** (by default) and sensitivity is recorded as '**Not sensitive'**.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Basking shark (*Cetorhinus maximus*) abundance has been shown to be related to plankton abundance within shelf-sea and headland fronts (Sims & Quayle, 1998; Sims, 2008; Speedie *et al.*, 2009) where they feed on the seasonal abundance of plankton, especially copepods (Sims, 2008). Important areas for basking sharks include migratory pathways, such as the Irish Sea and the Firth of Clyde (Sims *et al.*, 2003; Solandt & Chassin, 2013), and locations associated with feeding activity such as oceanic fronts e.g. tidal fronts in the English Channel and the Ushant Front, Brittany (Sims *et al.*, 2003) and other hotspots in the south and west of Cornwall and west coast of Scotland (Speedie & Johnson, 2008; Speedie *et al.*, 2009; Solandt & Chassin, 2013). Doherty *et al.* (2017a) reported that basking sharks undertook post-summer migrations along the western coast of the British Isles from the vicinity of the Faeroes south to North Africa (perhaps further) via continental shelf and oceanic waters (up to ca 1000 km) at depths of 50-200 m. Post-summer densities were greatest in the Celtic and Irish Seas, the west coast of Scotland, and continental shelf of the west coast of Ireland (Doherty *et al.*, 2017a). Doherty *et al.* (2017a) also reported that some individuals returned to the summer hotspots where they were tagged off the west coast of Scotland and the Isle of Man. Similarly, Doherty *et al.* (2017b), noted that three (of 36) tagged individuals showed inter-annual fidelity, returning to their tagged locations off the west coast of Scotland within a year of tagging. It is theoretically possible that obstruction due to an offshore wind farm, wave or tidal device arrays, or mariculture infrastructure could reduce or prevent access to fronts in the vicinity of headlands, currently used by this species. It is also theoretically possible that major engineering projects (e.g. barrages) in coastal seas could change the local hydrography significantly so that the fronts do not persist or do not form. However, no direct evidence of either situation was found to support this supposition.

Sensitivity assessment. Basking sharks have a broad geographic range and are capable of ocean migrations (Sims, 2008; Gore *et al.*, 2008; Doherty *et al.*, 2017a) so that obstruction or loss of access to current aggregation sites is likely to be temporary as the animals find other frontal systems to frequent or areas to feed. It is also likely that an individual would be able to swim around obstructions and continue its migration along another route, resulting in little more than small-scale energy loss. Although local 'hotspots' or aggregations may be lost, or move, the animal itself may experience some energy-loss at most. Therefore, resistance is assessed as **'High',** resilience as **'High'**, and sensitvity is assesed as **'Not sensitive'.**

Death or injury by collision	Medium Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

As a mobile and broadly distributed species, the basking shark could encounter anthropogenic objects (such as vessels and marine infrastructure) that may result in collisions. The basking shark is at risk from a collision with boat traffic because of their habit of feeding very close to the surface and at slow speeds (Sims, 2000; Speedie, 2017). There have been numerous accounts of basking shark collisions, particularly ship-strikes (Kelly *et al.*, 2004; Speedie & Johnson, 2008). The Marine Conservation Society (MCS) reported 63 basking sharks suffering from ship strike or entanglement in fishing gear between 1992 and 2013 (Solandt & Chassin, 2013). Despite having tough skin covered in dermal denticles, there is evidence of ship-strike causing scarring or injury and basking shark surveys routinely record evidence of injuries consistent with ship-strikes (Darling & Keogh, 1994; Bloomfield & Solandt, 2006; Speedie *et al.*, 2009). Speedie (2017) suggested that fatalities from boat collisions in both basking shark and humans had occurred but did not provide evidence to confirm the observation. Speedie (2017) also noted that breaching basking sharks were reported to land on and accidentally damage fishing vessels, although one individual was reported to have deliberately rammed and damaged a trawler.

Elasmobranchs are thought to be naturally resilient to some types of injury (Riley *et al.*, 2009; Chin *et al.*, 2015). For example, wounds several centimetres long were undetectable within weeks or months in blacktip reef sharks (*Carcharhinus melanopterus*) and fresh bite wounds healed in 3-5 weeks; while a deep bite wound 20 cm wide had closed within three days and almost completely recovered in 40 days (Chin *et al.*, 2015). Longer healing times were reported in grey nurse sharks (*Carcharias taruus*) where necrosis from hook injuries took over six months to heal. Healing rates were probably slower in cooler waters. Similarly, minor abrasions in white sharks (*Carcharodon carcharias*) in the cooler waters (ca 18-20°C) of the Guadalupe Islands were visible for several months but a large bite wound healed in about nine months (Domeier & Nasby-Lucas, 2007; Chin *et al.*, 2015). Riley *et al.* (2009) reported that a whale shark (*Rhincodon typus*) survived harpooning. It was observed with a wooden harpoon through its body and its poor condition suggested internal injuries. However, it was observed 331 days later having lost the harpoon and with signs of healing. Another whale shark was observed with a decapitated dorsal fin over four years, although the long-term effects on feeding and reproduction were unknown (Riley *et al.*, 2009). However, in the Canadian long-line fishery, hooking mortality varies between 10 and 31% in blue sharks (*Prionace glauca*), the shortfin mako (*Isurus oxyrhinus*) and porbeagle (*Lamna nasus*) but about half of hooked porbeagles and makos died during or after fishing, mostly with two days after release (Campana *et al.*, 2016). Capture by fishing is probably more traumatic than injury alone. But they also noted that their study could not detect delayed mortality due to altered behaviour and feeding or altered reproductive success (Campana *et al.*, 2016).

No evidence on healing rates in basking sharks was found. However, photo-identification and observational studies of basking sharks regularly record injuries, scars (including lamprey scars), notches in fins, propeller injuries, ship-strikes, and marks from nets or ropes (Speedie & Johnson, 2008; Speedie *et al.*, 2009; Solandt & Chassin, 2013; Gore *et al.*, 2016). These observations suggest that the basking shark can heal and recover from a range of injuries.

Sensitivity assessment. It is difficult to quantify the impact of collisions on the basking shark. However, with 63 reported collisions over 21 years (Solandt & Chassin, 2013) the occurrence appears to be relatively low, although Speedie *et al.* (2009) suggested incidents were increasing. Sharks can heal a wide variety of injuries quickly, particularly in the larger species. The evidence from nurse angel sharks, white sharks, and whale sharks suggests that minor injuries in basking sharks might heal within a few months while even significant (but not fatal) injuries might heal within a year. However, there is no evidence of delayed or long-term effects on feeding and reproductive success. Mortalities may go un-noticed if the affected individual sank to the seabed but no documented evidence of mortalities was found. Therefore, resistance is assessed as **'Medium'** as a precaution to represent the potential for some mortality but with 'Low' confidence due to the lack of direct evidence. Hence, resilience is assessed as **'Medium'** (2-10 yrs), and sensitivity as **'Medium'**.

Visual disturbance	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The basking shark is thought to be relatively tolerant of visual presence (Compagno, 1984; Speedie & Johnson, 2008). They have very small eyes in proportion to their body (Shark Trust, 2010), suggesting that vision is not a key sensory mechanism in this species. However, if disturbed by boats, individuals have been reported to dive and move away from the area (Bloomfield & Solandt, 2006). They have also been reported to be relatively unaware of surface vessels (Speedie & Johnson, 2008). Basking sharks killed by the prior harpoon fishery were shot at very close range and they generally show little reaction to being tagged. Speedie & Johnson (2008) noted that slow-moving vessels elicit hardly any response when groups of basking shark are feeding. The Marine Conservation Society (MCS) received accounts of behavioural changes in the basking shark, from experienced wildlife observers in the Isle of Man. In the accounts, courtship-like behaviour appeared to be disturbed by an approaching motorised craft, at a range of 1 km (Bloomfield & Solandt, 2006). On the other hand, at Gwennap Head, Seawatch Southwest wildlife observers (in 2007) began to see a change in behaviour when vessels came within 10 m of individuals (Bloomfield & Solandt, 2006). Observations from Gwennap Head by Seawatch Southwest wildlife observers in 2007 reported that the sharks only showed altered behaviour when vessels approached very close to them (within 10 m) (see 'Noise' above). The impact of visual disturbance may be magnified in tourist areas where disturbance by boat traffic and marine tourism activities is more frequent (Speedie & Johnson, 2008).

Sensitivity assessment. Visual disturbance appears to elicit a variety of reactions in the basking shark. Different outcomes documented include diving and moving away from the disturbance, disruption of courtship-like behaviour (Bloomfield & Solandt, 2008) or staying relatively undisturbed (Compagno, 1984; Speedie *et al.*, 2009). However, the response of basking shark to boats may be due to either their noise or visual disturbance (see 'Noise'). If visual disturbance or noise from passing vessels altered behaviour it would likely experience some energy-loss at most. Therefore, resistance has been assessed as **'High'**, resilience as '**High'** (by default), and sensitivity is assessed as '**Not sensitive'.**

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant - the basking shark is not subject to genetic modification or translocation for any commercial or conservation purposes.

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

There were no reports of direct impacts of invasive species on the success of *Cetorhinus maximus*. However, there is the potential for indirect threats caused by invasive species lower down in the food chain. As a zooplanktivore, any invasive species impacting on the zooplankton assemblage is likely to indirectly impact the basking shark by altering food availability. An example is *Mnemiopsis leidyi*, an invasive ctenophore native to North and South America feeds on zooplankton (Colin *et al.*, 2010). This species has already been found in the Mediterranean, Baltic and North Seas, however little is known about its future impacts.

Sensitivity assessment. There is currently **no evidence** to suggest that the basking shark is affected by the introduction of invasive species. However, this may require re-evaluation as more information becomes available.

Introduction of microbial pathogens	Medium Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

The first account of disease in the basking shark was reported by Dagleish *et al.* (2010) based on the post-mortem of a juvenile male found on Musselburgh beach, East Lothian, UK, in October 2007. Pyogranulomatous meningoencephalitis was found alongside multifocal, myocarditis (damage and inflammation of heart muscle) with myocyte necrosis (muscle cell death), oedema (fluid build-up in body cavities) and haemorrhage. The exact cause of the disease was not found. However, the evidence suggested an infectious origin (possibly caused by bacteria) (Dagleish *et al.*, 2010). The study could not conclude whether the meningoencephalitis was the cause of repeated live-stranding and subsequent death of the shark. The specimen was found in south-east Scotland, where it is uncommon, which was likely due to the impact of the disease on navigation (Dagleish *et al.*, 2010). In addition, 27 basking sharks were reported to the UK Cetacean Stranding Investigation Programme (CSIP) between 2005 and 2010 (Deaville & Jepson, 2010); 14 were found stranded in England, 12 in Scotland and one in Wales. Of the 27 reported basking shark strandings, three were investigated at post mortem (two in Scotland and one in England. Of these, one was found to have died as a consequence of live-stranding, one from a generalised bacterial infection and one from a meningoencephalitis (Deaville & Jepson, 2010).

There have been multiple accounts of basking shark associated parasites. Matthews & Parker (1950) reported the presence of three types of parasitic copepod *Dinematura producta* (now *Dinemoura producta*), *Caligus rapax* and *Nemesis lamna* on *Cetorhinus maximus*. These were found on the surface of the skin and the gills. The effects of the copepods attachment varied from minor skin erosion (*Dinemoura producta)* to extensive gill damage (*Nemesis lamna).* Lampreys are also commonly found attached to basking sharks with little apparent damage (Matthews & Parker, 1950). Further, there have been accounts of blood flukes (*Hyperandrotrema cetorhini*) or endoparasitic flat worms, found in the heart of *Cetorhinus maximus* (Orélis-Ribeiro *et al.*, 2013). Despite little information about their impacts on basking sharks, they have been known to cause inflammation and a decrease in the physiological and mechanical efficiency of the infected organs in other fishes (Bullard & Overstreet, 2002).

Sensitivity assessment. Most parasites found on the basking shark are seemingly benign, except for blood flukes which are suspected to cause inflammation in the infected organ (Bullard & Overstreet, 2002). Individuals probably live with a number of parasites throughout their life with limited effect on their viability, which suggests a 'Low' sensitivity. But, the natural mortality of basking sharks is unknown (Sims, 2008). The reports by Dagleish *et al.* (2010) and Deaville & Jepson (2010) suggest that once infected, an individual basking shark may experience deteriorating health and death. Therefore, resistance is assessed as **'Medium'** to represent the potential for 'some mortality' due to disease in basking shark, but with 'Low' confidence due to the limited evidence. Hence, resilience is assessed as **'Medium'** and sensitivity as **'Medium'**.

Removal of target species	Low Q: High A: High C: Medium	Low Q: Low A: NR C: NR	High Q: Low A: Low C: Low

Historically, the basking shark has been fished throughout its range, most commonly by harpoon (for reviews of fishing methods see: Kunzlik, 1988; Fairfax, 1998). Exploitation by fisheries (for its valuable liver oil and fins) in the North East Atlantic began in the 1700s in Norwegian, Scottish and Irish waters, and ended in the mid-1800s after a decline in basking shark abundance. In this period, landings were as high as 1000 individuals per year in Irish waters (ICES, 2016). The Norwegian fishery restarted in 1920, later to be joined by the Scottish (the 1940s) and the Irish (1947). The Norwegians dominated the market by taking between 1266 and 4266 basking sharks per year (from the years 1959-1980), compared with lower numbers in Scottish (total estimate of 970 individuals, from the years 1946-1953) and Irish waters (average of 1475 individuals per year, from the years 1951-1955). Although the extent and scale of these fisheries are not well recorded, in the 51 years between 1946 and 1997, at least 105,730 sharks (mainly females) were likely to have been captured in the North East Atlantic (Sims, 2008) with peak landings (5266 metric tonnes) observed in 1979 (ICES, 2016). Most basking shark fisheries reported declines in landings before they were terminated (Sims *et al*., 2015).

North East Atlantic fisheries experienced a large decline in basking shark total catch with a total of 3680 t in 1977, compared with only 119 t in 2000 (ICES, 2016). Sims *et al.* (2015) stated that the overall result of fishery efforts was thought to have reduced the basking shark population to less than half of its original size over the previous three generation spans (>100 years). In 2001, Norway reduced its basking shark landing quota to zero tonnes (Sims *et al*., 2015), and in 2006 ICES advised a zero total allowable catch (TAC) placing the basking shark on the Prohibited Species List. It was also recommended that by-catch should be minimized (ICES, 2016). In addition, EU legislation prohibits Union fishing vessels from fishing basking sharks in all waters under Article 13 of the Council Regulation 2016/72 (ICES, 2016). This ban continues, however, dead or dying incidentally caught basking sharks can be landed, but must be reported. In the UK, the basking shark has been protected since 1998 (ICES, 2016).

It is not known whether the basking shark population has recovered since protective measures were initiated (Sims, 2008), however, there is some evidence for improvement. Public sighting schemes in some locations (e.g. Irish waters) have seen an increase in total abundance, but whether this reflects the basking shark population or an increase in public sightings efforts is unknown (Sims *et al*., 2015). In addition, though many countries have banned the targeted removal of this species, the increased demand for shark fins due to human consumption likely puts basking sharks at risk in less regulated areas (Sims, 2008) especially since its fins are amongst the most lucrative on the international market (Fowler, 2009).

Sensitivity assessment. Although direct fishing of basking shark is illegal in UK waters, fisheries is a potential threat in other areas. Sims *et al.* (2015) estimated that the overall result of past fishery efforts reduced the basking shark population to less than half of its original size over less than 100 years. Despite some signs of improvement (e.g. increases in public sightings in Irish waters), with a generation time of ca 34 years, the basking shark is unlikely to have fully recovered from this loss. Therefore, resistance is assessed as '**Low**', resilience as '**Low**' and sensitivity is assessed as '**High**'.

Removal of non-target species	Medium Q: Medium A: Medium C: Medium	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

The basking shark was reported to be a victim of entanglement in fishing gear (e.g. trawls, longlines, prawn and cod traps) in the Pacific Canadian waters (DFO, 2009; McFarlane *et al.*, 2009). In the North East Atlantic, there are anecdotal reports of the basking shark being incidentally caught in gillnet and trawl fishing gear (ICES, 2016). In 1993, 28 records of basking sharks entangled in fishing gear were reported in the Irish Sea (Berrow, 1994; Berrow & Heardman, 1994) and at least 22% of the sharks died as a result of the entanglement. Furthermore, the Marine Conservation Society (MCS) reported 63 sharks suffering from ship strike or entanglement in fishing gear between 1992 and 2013 (Solandt & Chassin, 2013). Entanglement in ropes and nets was reported from Scotland and south-west England (Bloomfield & Solandt, 2006). Basking sharks are also accidentally caught by towed gear (Francis & Duffy, 2002). Small numbers (130 individuals over 21 years) of incidentally caught basking sharks continue to be reported in the UK (Witt *et al.*, 2012). As a result of the zero total allowable catch (TAC) and the requirement of the EU fishing industry to discard all incidentally caught basking sharks, there is little recorded information about these incidents. It is also difficult to quantify the impacts (ICES, 2016). Although the impact of accidental removal by fisheries and entanglement on populations is not quantified, fishing gear poses a threat to individuals of this species and the population as a whole. Finally, the high value of shark fins to the Asian market may result in basking sharks that are found alive being killed instead of released (Bloomfield & Solandt, 2006), although there are currently no records of the practice taking place in the UK (Bloomfield & Solandt, 2008).

Sensitivity assessment. Although the impact of accidental removal by fisheries and discarded (ghost) fishing gear on *Cetorhinus maximus* populations cannot be quantified, fishing gear poses a threat to this species. A threat that is presumably still present, with small numbers (130 individuals over 21 years) of incidentally caught basking reported in the UK and at least 22% mortality due to entanglement in the Irish Sea (Berrow & Heardman, 1994; Witt *et al.*, 2012). Therefore, resistance is assessed as '**Medium',** resilience as '**Medium'**, and sensitivity is assessed as '**Medium'**.

Importance review

Policy/legislation

Berne Convention	Appendix II
Wildlife & Countryside Act	Schedule 5, section 9
UK Biodiversity Action Plan Priority	☑
Species of principal importance (England)	☑
Species of principal importance (Wales)	☑
Scottish Biodiversity List	☑
OSPAR Annex V	☑
IUCN Red List	Vulnerable (VU)
Priority Marine Features (Scotland)	☑
Convention on Migratory Species	Appendix I or II

Status

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

Non-native

Native	-		
Origin	-	**Date Arrived**	-

Importance information

Population size

There are currently no accurate estimates of the global population size of the basking shark (*Cetorhinus maximus*) (Sims, 2008). The longest ongoing basking shark public sighting scheme was initiated by the Marine Conservation Society (UK) in 1987 (Bloomfield & Solandt, 2006; Solandt & Ricks, 2009; Solandt & Chassin, 2013). By 2008, there were a total of 24,013 UK sightings recorded under this initiative (Sims, 2008). The project provides insight into yearly trends in basking shark presence and individual length estimates per sighting provide information on growth patterns. In 2013, ca 3,000 basking shark individuals were recorded in over 1,000 sightings (Solandt & Chassin, 2013). A smaller public sightings scheme was established in Ireland (1993) to estimate the population of *Cetorhinus maximus* specifically in Irish waters. It reported a total of 425 individual basking sharks in one year of observation, encompassing all Irish coasts (Berrow & Heardman, 1994).

Additional UK *Cetorhinus maximus* population information is provided by Sims *et al.* (1997; 2008, unpublished data), in the form of basking sharks observed per unit time, which allows yearly comparisons of abundance within a small location (500 km^2). These data showed that the years 1998 and 1999 had fewer sightings (0.01 and 0.02 sharks per hour, /hr), than the years prior (1995–1997: 0.10–0.35 /hr), and following (2000: 0.30 /hr and 2001: 0.14 /hr). This trend in surface swimming *Cetorhinus maximus* was positively correlated with the zooplankton data within this time, with more basking sharks reported during periods of higher zooplankton abundance (Sims, 2008).

Hoelzel *et al.* (2006) studied the genetic diversity of the global population of the basking shark. In the study, Hoelzel *et al.* investigated the nucleotide and haplotypic (a group of alleles of different genes that are inherited together) diversity of a control region of mitochondrial DNA (mtDNA). Samples were taken from the tissue of stranded or incidentally caught basking sharks from the western North Atlantic, eastern North Atlantic, Mediterranean Sea, Indian Ocean and western Pacific. The results indicated both low nucleotide and haplotypic diversity, with only six identified haplotypes found across the samples. Hoelzel *et al.* (2006) estimated an effective population size of only 8,200 individuals. The low genetic variation observed in their samples was thought to be due to a bottleneck event in the Holocene epoch (within the last 11,500 years).

Many local *Cetorhinus maximus* populations have declined due to fishing efforts including the North East Atlantic population (ICES, 2016). For example, it is thought that more than half of the European population was lost over 3 generation spans (Sims *et al.*, 2015). Despite this, the current global population status is considered stable by the IUCN (Sims *et al.*, 2015) and some public sighting schemes have seen an increase in total abundance. However, it is not known whether this is reflective of the basking shark population or an increase in public sightings efforts (Sims et al., 2015).

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