BASKING SHARK

Stock name: Basking shark
Latin name: *Cetorhinus maximus*
Geographical area: Northeast Atlantic (ICES subareas 1-2, 4-8, division 3a)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: The basking shark (*Cetorhinus maximus*, Cetorhinidae) is a coastal-pelagic species inhabiting boreal to warm-temperate waters of the continental and insular shelves with a strong tendency to aggregate in areas dominated by transitional waters between stratified and mixed water columns (Sims, 2008; Sims et al., 2006). Annual sightings of basking sharks are well documented wherever fronts are well defined. This species occurs along continental shelf-edge habitats where fronts are often present as well; travelling long distances to locate temporally discrete productivity 'hotspots' at shelf-break fronts (Sims, 2008; Sims et al., 2003). The basking shark has been recorded primarily from coastal areas, although their habitat range may be much larger, covering the epipelagic zone of entire ocean basins. However, sightings data away from coastal areas are generally lacking, indicating either 'hidden' abundance at depth in oceanic regions, or a general lack of basking sharks away from productive coastal zones (Sims, 2008; Southall et al., 2005).

PREY SPECIFICITY: In the North Atlantic, the basking shark feeds upon zooplankton, with calanoid copepods being the main prey group. *Calanus* and other copepods, in addition to fish eggs, cirripede, mysid larvae, decapod larvae, chaetognaths, larvaceans, polychaetes, cladocerans, fish larvae and post-larvae have been found near feeding or in basking shark stomachs (Matthews & Parker, 1950; Sims & Merrett, 1997; Sims, 2008). However, in other regions basking sharks can utilise larger zooplankton prey, e.g. *Sergestes similis*, Sergestidae (Mutoh & Omori, 1978). Basking sharks have been shown to respond to zooplankton gradients, showing that they are selective filter-feeders that chose the richest, most profitable plankton patches (Sims & Quayle, 1998). At small spatial scales, basking shark distribution and occurrence appear strongly linked to zooplankton abundance (Sims, 2008).

SPECIES INTERACTION: The species competes with other filter-feeding species, e.g. larger whales, for zooplankton resources.

ADULT MOBILITY: Transatlantic and transequatorial migrations, as well as migrations into tropical areas and mesopelagic depths have been shown (Braun et al., 2018; Gore et al., 2008; Skomal et al., 2009). In the Northeast Atlantic, basking sharks undertake extensive horizontal and vertical migrations associated with the continental shelf and shelf edge throughout the year (Sims, 2008; Sims et al., 2003). Basking sharks have been recorded in the western Atlantic from Newfoundland to Florida and from southern Brazil to Argentina. In the eastern Atlantic, records have been made off Iceland and Norway, and as far north as the Russian White Sea (southern Barents Sea), extending south to the Mediterranean. In the southern hemisphere basking shark has been located off the Province of Western Cape of South Africa. In the Pacific Ocean basking shark occur along the East-Asian coast, from Japan to China and further south off Australia south of 25 °N and around New Zealand. In the eastern Pacific it occurs from the Gulf of Alaska to Baja California and from Peru southwards to Cape Horn (Compagno, 1984; Konstantinov & Nizovtsev, 1980; Wood, 1957). In both oceans it is missing from the tropics.

DISPERSAL OF EARLY LIFE STAGES: The basking shark does not have planktonic early life stages.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: As an elasmobranch, this sensitivity attribute has marginal relevance.

COMPLEXITY IN REPRODUCTIVE STRATEGY: Reproduction in the basking shark has been studied only from anatomical examinations of fishery-caught individuals (Matthews, 1950; Sims, 2008). Behavioural studies indicate accumulation of individuals during the summer months and mating seasons and areas have been suggested (Sims, 2008). Spatial and temporal complexity is assumed due to the following reproductive behaviours: 1. seasonal reproduction, during summer (i.e. initiation with environmental cues) and 2. migration and accumulation of individuals in specific mating areas.

SPAWNING CYCLE: The period of gestation is not known with any certainty, but estimates range from 1 year to as high as 3.5 years using length–frequency data (Parker & Stott, 1965; Sims, 2008). There is only one published record of a pregnant female being captured, giving birth to six pups (1.5-2.0 m) (Sund, 1943). Therefore, if this number of pups is representative of normal parturition rates, i.e. 6 pups every 1-3.5 years, it seems the basking shark exhibits low fecundity even when compared to other relatively large-bodied ovoviviparous sharks (Compagno, 1984; Sims, 2008).

SENSITIVITY TO TEMPERATURE: Despite a relatively wide range of thermal tolerance, basking sharks may show preferences for particular water temperatures (Sims, 2008; Skomal et al., 2004). In the Northeast Atlantic and especially in European shelf and shelf-edge habitats during summer-, autumn- and wintertime, the environmental temperature ranges 8-16 °C (Sims, 2008; Sims et al., 2003). In the Northwest (NW) Atlantic, one extremely spatially distributed shark individual occupied temperatures between 5.8 and 21.0 °C but recorded 72% within temperature ranges of 15.0 and 17.5 °C (Skomal et al., 2004) indicating potential temperature optima. Long-term sightings indicate that the number of basking sharks observed was highly correlated with sea surface temperature (SST) and the lagged effect of SST in the previous month among other abiotic factors (Cotton et al., 2005). Over large spatiotemporal scales, this correlation suggests that annual changes in the number of basking sharks recorded at the surface are probably closely related to the availability of climate-driven thermal habitats, which may also influence zooplankton abundance and distribution (Cotton et al., 2005; Sims, 2008). Although movements, longer-term distributions and population abundance of basking shark under climate variations have not been studied rigorously, a recent study (Cotton et al., 2005) supports the hypothesis that at small scales, behavioural responses due to foraging movements are linked by broad-scale responses to temperature variation (Sims, 2008).

SENSITIVITY TO OCEAN ACIDIFICATION: Basking sharks are feeding on zooplankton; any impact of ocean acidification (OA) on the composition of the zooplankton community and hence its nutritional value will modify the sharks' ecological traits. The North Sea and the Norwegian Sea are predicted to decline in pH between 0.8 and 1.2 by 2046 (NORWECOM.E2E). As basking sharks migrate between vital areas of, e.g. mating and pupping, they will be exposed to a variety of OA levels. Potential negative behavioural and physiological effects on, e.g. hunting behaviour and growth have been shown for predatory shark species and were even pronounced when coupled with other stressors like increasing temperatures (Pistevos et al., 2015, 2017; Rosa et al., 2017). It is not clear to what extend these effects will impact lower trophic level species like the basking shark, but issues with, e.g. sense of orientation, are likely to also affect these species in their detection ability of thermal fronts and the pursuit of concentrated zooplankton masses. Especially when coupled with SST increases, this could negatively impact the basking shark. Explicit research is however lacking.

POPULATION GROWTH RATE: Sexual maturation of female basking sharks is thought to be reached between 8.1 and 9.8 m (possibly at ages between 16 to 20 years), whereas males mature between 5 and 7 m (between 12 and 16 years) (Compagno, 1984; Sims, 2008). Individuals between 9.8 and 12.2 m have been reported, therefore 10-12 m appears to be a maximum length, even though this information is not known precisely (Sims, 2008). The growth rate of basking sharks is not known exactly but has been estimated between 0.43 m and 0.86 m per year (Sims, 2008). Longevity is estimated at about 40-50 years according to this mentioned estimation (Pauly, 1978).

STOCK SIZE/STATUS: There is no longer any directed fishery for basking shark within the ICES area. Since 2007, the species has been listed as a prohibited species on EU fisheries regulations and EU vessels should release/discard any by-caught individuals. Norwegian vessels may land deceased specimens but should release live specimens. Since 2013, reported landings have been <500 kg (ICES, 2019). The current status of the stock is unknown. ICES Working Group on Elasmobranch Fishes (WGEF) considers that no directed fishery should be permitted unless a reliable estimate of a sustainable exploitation rate is available. Proper quantification of bycatch, fate and discarding, in numbers and estimated weight, is required (ICES, 2019).

OTHER STRESSORS: Increased surface feeding activity during the summer months increases interactions between the sharks and for example boat traffic and fishing activities, both industrial and recreational. They are popular targets of wildlife tourism which can also exert stress on individuals in certain local hot spots (Sims, 2008). Although there is currently no targeted fishery for basking sharks in the Northeast Atlantic, they get lethally entangled in fishing nets due to their size (ICES, 2019). There are potential impacts on basking sharks associated with habitat loss and degradation. Coastal development, pollution, and bottom fishing affect coastal water quality and food sources of this filter-feeding species (Beaugrand et al., 2002). Research supports the hypothesis that behavioural responses at small scales are linked by broad-scale responses to climate changes (Sims, 2008). Basking sharks are also particularly in danger of ingesting plastics, especially macroplastics, similar to whales.

Scoring of the considered sensitivity attributes

Sensitivity attributes, climate exposure based on climate projections allowing the evaluations of impacts of climate change, and accumulated directional effect scoring for basking shark (*Cetorhinus maximus*) stock in ICES subareas 1-2, 4-8, division 3a. L: low; M: moderate; H: high; VH: very high, $Mean_w$: weighted mean; N/A: not applicable. Usage: this column was used to make ad hoc notes, including considerations about the amount of relevant data available: 1 = low, 2 = moderate; 3 = high. N/A = not applicable.

Basking shark (*Cetorhinus maximus*) in ICES subareas 1-2, 4-8, division 3a

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	1	1	2	1	**2.6**		
Prey Specificity	0	1	2	2	**3.2**		
Species Interaction	0	2	2	1	**2.8**		
Adult Mobility	3	2	0	0	**1.4**		
Dispersal of Early Life Stages	0	0	0	5	**4.0**		
ELH Survival and Settlement Requirements	5	0	0	0	**1.0**		
Complexity in Reproductive Strategy	0	3	2	0	**2.4**		
Spawning Cycle	0	0	2	3	**3.6**		
Sensitivity to Temperature	1	3	1	0	**2.0**		
Sensitivity to Ocean Acidification	0	2	2	1	**2.8**		
Population Growth Rate	0	0	1	4	**3.8**		
Stock Size/Status	0	0	2	3	**3.6**		
Other Stressors	0	2	2	1	**2.8**		
Grand mean					**2.77**		
Grand mean SD					**0.91**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	3	2	0	**2.4**		1
Temperature 100 m	0	0	0	0		N/A	
Temperature 500 m	0	0	0	0		N/A	
Bottom Temperature	0	0	0	0		N/A	

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O_2 (Surface)	4	1	0	0	**1.2**		-1
pH (Surface)	4	1	0	0	**1.2**		-1
Gross Primary Production	1	3	1	0	**2**		1
Gross Secondary Production	1	3	1	0	**2**		1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.76**		
Grand mean SD					**0.54**		
Accumulated Directional Effect					**–**		**4.0**

***Accumulated Directional Effect*: POSITIVE**	**4.0**

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