NORTHERN HAKE

Stock name: European hake (Northern stock)
Latin name: *Merluccius merluccius*
Geographical area: Bay of Biscay – west of the British Isles – North Sea – Northwest Norwegian coast – Skagerrak-Kattegat (ICES subareas 2, 4, 6 and 7, divisions 3.a, 8.a-b and 8.d)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: European hake (*Merluccius merluccius*, Merlucciidae) is considered a pronounced generalist with its extensive distribution including, from the south to north, the Gulf of Guinea, Black Sea, Mediterranean Sea east of the Iberian Peninsula, Bay of Biscay, west of the British Isles to Iceland, North Sea and Skagerrak, and the Norwegian coast (Murua, 2010). The "Northern hake" is defined as the part of the European hake population covering the area to the north of the Cap Breton canyon in the Bay of Biscay, 43 °38' N (ICES, 2019). Some authors (Roldán et al., 1998) indicate genetic separation at Gibraltar between the Mediterranean hake and the Northern hake, while others (Westgaard et al., 2017) suggest sub-populations west of Shetland, based on genetic variation between hake in the Kattegat, fjords on the Norwegian west coast, and north of 62 °N. Records of European hake observations and catches from fisheries west of the Shetland Islands date back to the beginning of the 20th century (Brunchorst, 1898; Hickling, 1927). During the last decade juveniles as well as large mature hake have been observed in scientific survey in the Lofoten region (68 °N), indicating that the species is gradually expanding its area of distribution northwards.

PREY SPECIFICITY: Hake is a top predator in the demersal community in the Northeast Atlantic (Murua, 2010). In the North Sea, Norwegian Sea and Skagerrak hake adults feed on Norway pout, mackerel, blue whiting, adult herring, saithe, whiting, shrimps and juvenile cod, while juveniles of hake prefer microzooplankton, at least during summer (Cormon et al., 2014; Werner, 2015). In the western and southern part of its distribution hake prey on sprat, mackerel, horse mackerel, blue whiting and Norway pout (Du Buit, 1996), while in the Bay of Biscay the diet comprises horse mackerel, anchovy, blue whiting, crustaceans and cephalopods (Guichet, 1995). Additionally, length-dependent cannibalism has been observed in both the Celtic Sea and Bay of Biscay (Mahe et al., 2007). In a study from the Celtic Sea where prey of hake and other gadoids were analysed, hake diverted from the other species by an abrupt change in prey selection from young fish to adults (Pinnegar et al., 2003). Up to lengths of 25-30 cm hake feed uniquely on crustaceans, while above 35 cm hake switches entirely to pelagic fish such as blue whiting, horse mackerel, and clupeids.

SPECIES INTERACTION: The area of distribution of hake in the North Sea overlaps with that of boreal gadoids like saithe and cod (Cormon et al., 2014). Given similarities in feeding behaviour and prey preferences (Du Buit, 1991; Werner, 2015) the recent increase in hake abundance in the North Sea (Baudron & Fernandes, 2015; Staby et al., 2018) may lead to heightened interspecific competition for prey species like Norway pout (Cormon et al., 2014). Hake, being a widely distributed top predator, will in the future North Sea most likely reap larger benefits from climate changes compared to the boreal gadoid species like cod and haddock which may be confronted with less optimal habitat conditions particularly in the southern part of their distribution.

ADULT MOBILITY: European hake has a wide latitudinal distribution (Heessen & Murua, 2015; Valero et al., 2006; Westgaard et al., 2017), and has particularly in summer during the last two decades expanded into the central and northern North Sea (Staby et al., 2018; Werner et al., 2016). Juvenile hake has been observed as far north as the Lofoten islands during the last decade (Sundby et al., 2017). Occurrence of spawning north of 62 °N along the Norwegian coast and an intra-annual variation in length frequency distribution are indicative of spawning migrations and more complex population dynamics particularly in the northern range than previously considered (Werner et al., 2016). Genetic studies indicate high degree of connectivity among various components of the Northern hake stock (Pita et al., 2011), though another study (Westgaard et al., 2017) also showed that sub-populations may be present west of the Shetland Islands (see above).

DISPERSAL OF EARLY LIFE STAGES: Eggs are probably relatively deeply distributed, at least west of the British Isles (Coombs & Mitchell, 1982). The dispersion of eggs and larvae is in most places moderate. It should be emphasized here that the dispersion of eggs and larvae is generally site-dependent; ambient circulation patterns and ambient temperature (determining egg incubation time and larval stage duration) are the two most important factors for offspring dispersal. For example, dispersion is much larger from the spawning site in the open waters of the North Sea than in the Norwegian fjords where the circulation dynamics in many cases contribute to eggs and larval concentrations through retention rather than dispersion. Colonization of new areas are to a very low extent dependent on the degree of egg and larval dispersal, but rather on the mature part of the stock to select new spawning areas.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: The early stages of hake have a pelagic duration of about 6 ± 1 weeks in the Bay of Biscay and Celtic Sea (Kacher & Amara, 2005). In this area 0-group hake is observed at bottom depths around 100 m, which means that this group is found rather close to the coast in the Bay of Biscay and more offshore in the Celtic Sea, and, assuming a linear age-size relationship, grow to a length of ~24 cm in the first year (Kacher & Amara, 2005). Assuming similar growth patterns in the North Sea and Norwegian waters as in the Bay of Biscay, 0-group hake occurs at depths between 50-150 m, and in the Skagerrak at < 100 m (Staby et al., 2018), where they are typically detected over muddy bottom.

COMPLEXITY IN REPRODUCTIVE STRATEGY: Mature and spawning hake can be observed in a wide range of habitats (open water, coastal and fjordic habitats) and has seemingly adapted to the prevailing environmental conditions (Werner et al., 2016). Temperatures at 100 m depth in these areas ranges from 17 °C on the southern fringe to about 7 °C in the northern fringe. Members of the hake family can generally tolerate and reproduce at very low oxygen concentrations (Sundby et al., 2001), which would enable it to cope with the low-oxygen Baltic conditions. The shallow sill into the Baltic is probably the largest impediment for further expansion into the Baltic Sea. The slope conditions along the European continental shelf make the entire area suitable for hake.

SPAWNING CYCLE: Hake is a batch spawner (Murua, 2010) and, depending on location, the species spawns at different times of the year with variation in spawning season duration (Werner et al., 2016). In contrast to spawning throughout nearly the whole year in southern areas, hake in the North Sea and the Norwegian Sea appear to have a shorter spawning season from mid-summer to early autumn, which falls outside the spring bloom period (Groison et al., 2011; Werner et al., 2016) (Staby, unpublished data). In theory this would be the most predominant constraint for further poleward displacement since the extreme spring-bloom dynamics from around the Arctic Circle require an adaptive behaviour to limit the spawning season to a narrower time window during spring (Sundby et al., 2016). However, the presence of juvenile as well as spawning hake in Norwegian coastal waters as late as September/October is indicative of not only that environmental conditions and prey availability are favourable for larval growth, but also that survival throughout the winter period is perceptible.

SENSITIVITY TO TEMPERATURE: Because of its generally deep distribution adult hake is less vulnerable to high summer temperatures as well as low winter temperatures occurring in the surface layers. Also eggs and larvae have been observed at greater depth (Coombs & Mitchell, 1982) than eggs and larvae from other species that often are most abundant in the upper 30 m of the water column. The wide latitudinal range of the species also indicates its wide thermal tolerance (Dulvy et al., 2008). On the other hand, with its northernmost distribution near the Arctic Circle it may have reached its northernmost distribution according to the hypothesis that there is a limit to how far temperate species may advance poleward due to the spring-bloom dynamics at these high latitudes controlled by the seasonal light cycle (Sundby et al., 2016).

SENSITIVITY TO OCEAN ACIDIFICATION: Some hake species are tolerable to very low oxygen concentrations, e.g. Cape hake (*Merluccius capensis*, Merlucciidae) adults as well as eggs can tolerate oxygen concentrations in the oxygen minimum zone (OMZ), down to 0.3 ml/l (Sundby et al., 2001). These sub-oxic regions coincide with high ocean acidification (OA). Limited information on sensitivity to OA exists elsewhere. However, the general adaptation to OMZs is indicative of that hake might also have a robust physiology to changes in OA.

POPULATION GROWTH RATE: The Northern hake stock was below B_{lim} – the limit reference point for spawning stock biomass (SSB) from the mid-1990s to 2000, with a concurrent decrease in size at maturity (Domínguez-Petit et al., 2008). Until 2008 the stock was at a low level and stable, and since then SSB has increased to record levels (ICES, 2019). In the period after 2008 hake also expanded its spawning areas in the northern and central part of the North Sea (Staby et al., 2018; Sundby et al., 2017). The rapid increase in SSB of Northern hake coincides with observed increase in abundance in the North Sea, especially during summer months (Staby et al., 2018). Currently the Northern hake is experiencing a positive stock development, which may also be supported by a comparatively low fishing mortality, particularly in the North Sea.

STOCK SIZE/STATUS: Presently the stock is at very high level, with SSB estimated well above 250,000 tonnes and an estimated total biomass well above 300,000 tonnes (ICES, 2019). Total hake catches have increased from 51,190 tonnes in 2008 to nearly 100,000 tonnes in 2018, and the fishing mortality (F) was estimated at 0.24 in 2019.

OTHER STRESSORS: Hake in its northernmost area, where it presently is also most abundant, experience near optimal conditions with respect to temperatures, oxygen, and bottom topography. Moreover, this is a top predator that exploits a high diversity of prey species. Hence, F is the main stressor, although F declined steadily from 2005 (≈ 1.0) and then flattened out from 2012 (≈ 0.25), i.e. around F consistent with achieving maximum sustainable yield (F_{MSY}); the stock currently shows full reproductive capacity.

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 European hake (*Merluccius merluccius*) in ICES subareas 2, 4, 6, and 7, divisions 3.a, 8.a-b and 8.d. 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.

European hake (*Merluccius merluccius*) in ICES subareas 2, 4, 6, and 7, divisions 3.a, 8.a-b and 8.d

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	4	1	0	0	**1.2**		
Prey Specificity	4	1	0	0	**1.2**		
Species Interaction	3	2	0	0	**1.4**		
Adult Mobility	3	2	0	0	**1.4**		
Dispersal of Early Life Stages	1	3	1	0	**2.0**		
ELH Survival and Settlement Requirements	1	3	1	0	**2.0**		
Complexity in Reproductive Strategy	2	3	0	0	**1.6**		
Spawning Cycle	2	3	0	0	**1.6**		
Sensitivity to Temperature	3	2	0	0	**1.4**		
Sensitivity to Ocean Acidification	4	1	0	0	**1.2**		
Population Growth Rate	0	3	2	0	**2.4**		
Stock Size/Status	0	2	3	0	**2.6**		
Other Stressors	4	1	0	0	**1.2**		
Grand mean					**1.63**		
Grand mean SD					**0.48**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	0	0	0	0		N/A	
Temperature 500 m	0	0	0	0		N/A	
Bottom Temperature	0	0	2	3	**3.6**	3	1
O_2 (Surface)	5	0	0	0	**1.0**	3	0
pH (Surface)	4	1	0	0	**1.2**	1	-1
Gross Primary Production	3	2	0	0	**1.4**	1	1
Gross Secondary Production	0	3	2	0	**2.4**	1	1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.92**		
Grand mean SD					**1.08**		
Accumulated Directional Effect					**–**		**6.2**

***Accumulated Directional Effect*: POSITIVE**	**6.2**

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