Stock name: Beaked redfish
Latin name: *Sebastes mentella*
Geographical area: Norwegian and Barents Seas (ICES subareas 1 and 2)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: The beaked redfish (*Sebastes mentella*, Sebastidae) stock ranges from around 62 °N in the South to the Polar Front in the North. During its lifecycle, it switches from a semipelagic lifestyle in the Barents Sea, in the juvenile and immature phase, to a primarily pelagic existence in the Norwegian Sea as adults. Juvenile beaked redfish have a generally more northern and eastern distribution than the adults, as they mostly depend on where they are initially transported by the warm Atlantic currents (Barsukov et al., 1986; Zakharov et al., 1977). At ages 4 to 6 they start to migrate towards the shelf slope. This applies to about 80% of the stock with the remainder remaining semi pelagic, living within 10 m of the bottom on the shelf and slope (Anonymous, 2009). In the western Atlantic fishes of the genus *Sebastes* were observed to avoid sandy substrate, preferring either coarse substrates, from gravel onwards or fine-grained sediment like silt (Kelly & Barker, 1961; Pikanowski, 1999; Scott, 1982b, 1982a). Either substrate is widely available in the Barents Sea. Juveniles may profit from hard structured which are more limited in the Barents Sea. The adults in the Norwegian Sea are centred around the deep scattering layer at 2-3 °C (ICES, 2019b). Given the wide-open Norwegian Sea beaked redfish may avoid unfavourable temperature conditions by migrating in the water column leading to adults little affected by temperature changes.

PREY SPECIFICITY: Redfish favours relatively small prey items, as juveniles and as adults (Dolgov & Drevetnyak, 2011; Drevetnyak, 1999). Early life stages (ELS) prefer copepod-nauplii over larger zooplankter for a longer period than other species, which does, however, not prevent preying on larger copepod-stages. At some times, larvae of Appendicularia or Bivalvia can form significant proportions of the diet in ELS (Jakobsen & Ozhigin, 2011). Other than the larvae of many other fish species redfish larvae can digest copepod eggs, which may give an advantage if other prey items are not available (Anderson, 1994). As adults, beaked redfish continues to feed on small prey, primarily on large zooplankter like Euphausiidae and Hyperiidae (Dolgov & Drevetnyak, 2011). Small fish or juveniles become available prey for redfish at sufficient size. However, mesopelagic fish are mostly absent from the Barents Sea and juveniles of the genus *Sebastes* as well as other taxa are separated by habitat. Therefore, fish prey plays a minor role compared to the western Atlantic (Drevetnyak, 1999). The part of the adult population that resides in the Norwegian Sea may feed on mesopelagic fish more substantially.

SPECIES INTERACTION: Interactions with other fish species change largely from prey in ELS to adults as predator during the lifecycle of beaked redfish. One of the main predators of juvenile redfish are cod and halibut (ICES, 2019a). Likewise, adult redfish are also known to be cannibalistic and prey also on juveniles of other fish species. Since increasing temperatures are favouring North East Arctic cod (Planque & Frédou, 1999), whilst adult redfish are thermally separated from nurseries (Barsukov et al., 1986; Zakharov et al., 1977), increased predation though not prey-availability may induce a net loss.

ADULT MOBILITY: Adult redfish migrate over large regional scales, from the open Norwegian Sea to the shelf edge and back again (Mukhina et al., 1992; Mukhina & Drevetnyak, 1995; Zakharov et al., 1977). Since the majority of the population resides in the offshore Norwegian Sea the wide habitat allows probably simple trait adjustments to climate change (Anonymous, 2009). Also, they should be able to avoid unfavourable temperatures by moving vertically in the water column.

DISPERSAL OF EARLY LIFE STAGES: The larvae of beaked redfish are born in only roughly defined areas along the shelf break and are dispersed far more than a 100 km from their origin (Mukhina et al., 1992; Mukhina & Drevetnyak, 1995). Larval transport is either into the Barents Sea or along the shelf edge towards Svalbard (Drevetnyak & Nedreaas, 2009). As the warm Atlantic currents may be influenced by variable freshwater inflow and increased melting of sea-ice in the western Atlantic, they may decrease in strength which may have potentially negative effects on larval dispersion.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: Beaked redfish extrudes larvae that directly start feeding after parturition (Pikanowski, 1999). They are able to digest copepod-eggs which may give them an advantage in case of a mismatch between the start of larval feeding and a the spring bloom (Karamushko & Karamushko, 1995; Konchina, 1970).

COMPLEXITY IN REPRODUCTIVE STRATEGY: The reproduction of beaked redfish is increased in complexity by the spatial and temporal separations of mating, fertilization and extrusion of larvae (Zakharov et al., 1977). Males mate with females on the feeding grounds in the open Norwegian Sea in summer and autumn. Females store the sperm to fertilize the eggs in late winter (Jakobsen & Ozhigin, 2011), whilst the female migrates towards the shelfwards (Travin, 1952). This process entails a high rate of atresia with many egg follicles getting reabsorbed depending on the condition of the female. Given the long storage period of the sperm, the success of fertilization may be reduced compared to immediate fertilization. The larvae are extruded along the shelf break from mid-March to April ending into early May at a rather developed state but in low numbers compared to, e.g. cod of corresponding size (Mukhina & Drevetnyak, 1995; St-Pierre & De Lafontaine, 1995).

SPAWNING CYCLE: Reproduction of beaked redfish is temporally split in two phases. One critical is the extrusion of larvae that typically takes place within a timeframe from mid-March to the end of April and occasionally into May (Jakobsen & Ozhigin, 2011). As redfish larvae can digest copepod-eggs, they may be able to cope with a slight shift in the spring bloom but remain vulnerable if greater shifts occur (Anderson, 1994).

SENSITIVITY TO TEMPERATURE: According to the red fish surveys by IMR in the Irminger and Norwegian Seas *S. mentella* is mainly observed at around 4 °C and 3 °C, respectively (ICES, 2018, 2019b). Observations in the Irminger Sea indicate that the fish change depth to avoid temperatures outside their preferred range (Pedchenko, 2005). However, this may not indicate the limit of the species temperature tolerance, as a range of 0-13 °C is estimated for the genus *Sebastes* in the Gulf of Maine (Kelly & Barker, 1961; Scott, 1982a). In a Norwegian Sea survey in 2019 low numbers of *S. mentella* were also observed at temperatures slightly <0 °C (ICES, 2019b).

SENSITIVITY TO OCEAN ACIDIFICATION: Effects of ocean acidification (OA) are potentially direct and indirect and may affect ELS more than adults. At least one study indicated a sensory effect of CO_2 levels on the congener *Sebastes diploproa*, increasing the anxiety which lasted for a certain period after the pH was returned to normal (Hamilton et al., 2014). Indirectly, juveniles attempting to hide from predators among benthic structures may lose refuges if calcifying biota are negatively affected by OA (Andersson et al., 2008; Turley et al., 2007). Additionally, lowered crustacean zooplankton abundances due to OA may negatively affect beaked redfish (Whiteley, 2011).

POPULATION GROWTH RATE: *S. mentella* is a long-lived, slow growing and late maturing species (ICES, 2019a). Therefore, it scores high in most indicators of the table provided.

STOCK SIZE/STATUS: Since the successful rebuild of the stock, the spawning stock biomass (SSB) of *S. mentella* fluctuates around 800 kilotonnes, with a total biomass of 1.3 million tonnes in the latest stock assessment estimates. This is four times the biomass maximum sustainable yield (B_{MSY}), approximated as biomass precautionary reference point for biomass (B_{pa}) ≈ 315 kt. However, due to a high uncertainty in the stock estimates caution is required and vulnerability may therefore be higher (ICES, 2019a).

OTHER STRESSORS: The only stressor not yet considered is the potential future exploration and subsequent extraction of oil in the Barents Sea and the larval extrusion areas (Sundby et al., 2013). Aside from direct fisheries, bycatch of juveniles in other fisheries, such as that for shrimp, may be considered as 'other stressor', too.

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 Beaked redfish (*Sebastes mentella*) stock in ICES subareas 1 and 2. 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.

Beaked redfish (*Sebastes mentella*) in ICES subareas 1 and 2

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	1	3	1	0	**2.0**		
Prey Specificity	1	2	2	0	**2.2**		
Species Interaction	1	2	2	0	**2.2**		
Adult Mobility	3	2	0	0	**1.4**		
Dispersal of Early Life Stages	3	2	0	0	**1.4**		
ELH Survival and Settlement Requirements	1	3	1	0	**2.0**		
Complexity in Reproductive Strategy	0	2	3	0	**2.6**		
Spawning Cycle	0	1	3	1	**3.0**		
Sensitivity to Temperature	0	3	2	0	**2.4**		
Sensitivity to Ocean Acidification	1	3	1	0	**2.0**		
Population Growth Rate	0	0	2	3	**3.6**		
Stock Size/Status	3	2	0	0	**1.4**		
Other Stressors	1	3	1	0	**2.0**		
Grand mean					**2.17**		
Grand mean SD					**0.64**		

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	3	2	0	0	**1.4**		1
Bottom Temperature	0	0	0	0		N/A	
O_2 (Surface)	0	0	0	0		N/A	
pH (Surface)	3	2	0	0	**1.4**		-1
Gross Primary Production	3	2	0	0	**1.4**		1
Gross Secondary Production	2	3	0	0	**1.6**		1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.45**		
Grand mean SD					**0.10**		
Accumulated Directional Effect					**–**		**3.0**

***Accumulated Directional Effect*: POSITIVE**	**3.0**

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