ANGLERFISH

Stock name: Anglerfish
Latin name: *Lophius piscatorius*
Geographical area: Norwegian Sea and coastal areas (ICES subareas 1 and 2)
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Date: 10 February 2020

Stock Sensitivity Attributes

HABITAT SPECIFICITY: The distribution areas of the anglerfish (*Lophius piscatorius*, Lophiidae) range from Gibraltar to the southwestern Barents Sea, around the Faroe Islands and Iceland (Thangstad et al., 2006). Anglerfish in ICES subareas 1 and 2, mostly in 2a, is regarded as a separate management unit by the Working Group for the Celtic Seas (WGCSE), which assesses anglerfish in the neighbouring ICES areas. Genetic studies, however, could not proof any stock separation in ICES subareas 1 and 2. Thereby, particle-tracking studies indicated an interchange of larvae between spawning areas west of Scotland and further towards ICES divisions 2a, Faroes and Iceland (Hislop et al., 2001). Tagging experiments also show a wide mixing of anglerfish from different management units (Laurenson et al., 2005; Thangstad et al., 2006). The ICES Benchmark Workshop on Anglerfish Stocks in the ICES Area (WKAngler) (ICES, 2018) considered that most recruits in subareas 1 and 2 are from the southerly stock unit. Until an appropriate stock partitioning is defined, WKAngler (ICES, 2018) recommends to keep the anglerfish currently in subareas 1 and 2 as a separate management unit. Anglerfish is predominantly found on muddy, gravelly, and occasionally rocky substrates and can tolerate a wide range of depths, about 1,000 m (Caruso, 1986). Large specimens of over >40 cm total length were reported at depths between 90 to 2,600 m whereas, in shallower depths (53-316 m), smaller individuals were observed in the North Sea north of 56 °N, the Atlantic coast of the British Isles, the Norwegian Sea and the south-western Barents Sea (Hislop et al., 2000). Along the Norwegian coast in spring, mature females are observed at shallow depths or stranded on the beach.

PREY SPECIFICITY: Anglerfish is an opportunistic feeder, with a low degree of prey selectivity. Temporal prey availability and abundance are reflected by analyses of the stomach contents (Crozier, 1985). In addition to codfish, the most important food source, stomach contents analyses from commercial anglerfish catches off the coast of Norway revealed large amounts of herring (*Clupea harengus*, Clupeidae) (Woll et al., 1995). From anglerfish stomach contents at various locations around Shetland in different times of the year it was concluded that anglerfish is an opportunistic predator, only limited to manageable prey sizes. There is evidence from diet and tagging studies that anglerfish may migrate to areas where specific prey (e.g. sandeels) are seasonally or temporarily abundant (Laurenson, 2003).

SPECIES INTERACTION: Continued research on anglerfish diet and species assemblages may improve our understanding of ecological requirements of anglerfish. Independent to scarce literature the stock may be, due to its wide pelagic distribution, long migration habits and opportunistic feeding, little influenced by interspecific interactions. There are no reports of predators that specifically target adult *L. piscatorius* in European waters except from a study indicating cormorant birds (*Phalacrocorax* sp.) preying on anglerfish (Choisy & Jones, 1983). Possible seal predation through tail removal of captured fish has been described (Thangstad et al., 2006). Stomach content of a single sperm whale comprised anglerfish remains (Santos et al., 2002). In Faroese waters a few juvenile anglerfish specimens in stomach contents of large cod (*Gadus morhua*, Gadidae) was observed (Ofstad, pers. obs.). It is further likely that anglerfish early life stages (ELS) during the pelagic phase are heavily top-down controlled by other species, but no studies are available to confirm this assumption.

ADULT MOBILITY: The stock is site dependent during the spawning season but highly mobile at other times. From the distribution of demersal stages of British *L. piscatorius*, spawning grounds are assumed to occur in deep water (Hislop et al., 2001). In addition, they are reported at depths of 1,000-1,800 m (Thangstad et al., 2006) West of the British Isles. Observations lack to indicate whether Nordic stocks of anglerfish migrate to such depths to spawn, but large mature females were reported at 350 m depth far off the coast of western Norway (Woll et al., 1995). The results of 10 data storage tags (DSTs) showed that anglerfish, larger than approximately 70 cm, performs a seasonal offshore-onshore migration. Specimens migrate between shallow depths (< 200 m, feeding area) in summer and deeper waters (> 300 m, spawning area) in winter (Ofstad, 2013).

DISPERSAL OF EARLY LIFE STAGES: After spawning, egg ribbons ascend towards the surface, while the eggs complete their development until hatching. Pelagic anglerfish larvae (4 mm long) drift with surface currents for weeks to several months before juveniles (50-120 mm total length) settle on the inshore seabed (Hislop et al., 2000). In northern British waters, pelagic phase was described to last up to 120 days before settlement (Hislop et al., 2001). Settlement may occur hundreds of kilometres away from the spawning grounds (Thangstad et al., 2006).

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: Larval requirements are minimal or unknown. Stock requirements are not well understood, and recruitment is highly variable, especially the recruitment that occurs in ICES subareas 1 and 2 and appears to have a strong dependence on environmental conditions.

COMPLEXITY IN REPRODUCTIVE STRATEGY: The spawning in anglerfish occurs in an unusual way compared to most other marine fish species. Anglerfish eggs are released in a gelatinous, buoyant, and reddish to purple ribbons containing more than a million eggs and measuring up to 10 m long for 1 m wide (Thangstad et al., 2006). Consequently, eggs and newly emerged larvae distribution is highly aggregated. Such a ribbon or tube may constitute up to half of the mature female total weight. Unfortunately, no fecundity data are available (Fariña et al., 2008), and further research is required to determinate this important information, allowing to better understand reproductive investment and capacity of a stock to withstand fishery pressure (Thangstad et al., 2006). The broad gestation periods of observed female indicate either that gonadal development is long or that spawning is non-synchronous. Individuals may not spawn every season as suggested by the large number of spent/resting females in the catches (Staalesen, 1995). The reproductive events of anglerfish do not seem to be too dependent on temperature. Anglerfish tend to have as life-history strategy to withstand periods of poor environmental conditions by surviving until favourable conditions produce a strong year class, especially regarding recruitment in the ICES subareas 1 and 2 from spawning areas further south. Such strategy could become less favourable with climate change, as the conditions required for successful recruitment may become less frequent. How climate and environmental changes may influence the gelatinous and buoyant egg bands may be another characteristic that suggest complexity.

SPAWNING CYCLE: Spawning of mature, adult anglerfish occurs close to the seabed. Knowledge about location and timing of anglerfish spawning season in northern European waters (Hislop et al., 2001) is scarce due to the unusual way in which the spawning occurs (see previous paragraph). In deep waters (200-400 m depth) off the Faroese mature female anglerfish were observed in February and April at Skeivabanka southwest of the Faroes, the Faroe Bank and north of the Faroes (Ofstad, 2013). Together with observations of larvae and juveniles in the same areas marks possible important spawning areas around the Faroes, but the exact locations are still unknown. This is also indicated by the increasing percentage of mature anglerfish which was found with increasing depth in the waters around Shetland (Laurenson, 2003; Laurenson et al., 2001). Several studies suggest that the spawning season in *L. piscatorius* extends from November to June depending on areas (Fariña et al., 2008) but from late winter to summer in northern areas including Norwegian Sea and coastal areas (Thangstad et al., 2006). North-west of Scotland the largest number of spent females was found between April and July (Afonso-Dias & Hislop, 1996). The spawning strategy assumes anglerfish to be a total spawner, but still needs to be investigated. Mature females appear to carry eggs that are all at a similar stage and yet, no reports indicate females as batch spawner. Additionally, egg veils are usually several metres long, and so must surely be from a single spawning event (Chevonne Angus, North Atlantic Marine Centre, Shetland, and Kjell Nedreaas, IMR, Norway, pers. comm.).

SENSITIVITY TO TEMPERATURE: Anglerfish lacks a swim bladder and is widely vertically distributed but spawning is assumed to occur in deep water. The DSTs revealed that anglerfish prefers temperatures > 4 °C, usually between 6.5-11 °C (Ofstad, 2013). Vertical migrations, from the seabed (100-400 m) to near surface (< 10 m), or even at the surface is also reported. According to the Iceland groundfish survey, anglerfish is rarely found in waters with bottom temperatures < 5 °C. It has furthermore been confirmed in the survey that the area of Icelandic waters above 400 m where bottom temperature is more than 5 °C has doubled in size since 1985-1989. The changes in the distribution of anglerfish and increased stock size have thus co-occurred with rising water temperatures that have expanded suitable grounds for the species (Solmundsson et al., 2010, 2007). The anglerfish in the Northeast Atlantic occurs only in one province, but is thereby widely distributed (Spalding et al., 2007).
SENSITIVITY TO OCEAN ACIDIFICATION: The direct effect of ocean acidification (OA) on anglerfish is not well understood. The adult stock is mainly piscivore and is hence less dependent on sensitive prey to OA such as copepods pelagic shrimps, echinoderms, and crustaceans. The egg-bands and juvenile pelagic stages may be more sensitive to OA than the adults. Variable depth distribution may cause a moderate exposure to acidification.

POPULATION GROWTH RATE: WKAngler (ICES, 2018) suggests the following population growth and maturation parameters for anglerfish in ICES subareas 1 and 2: von Bertalanffy K=0.12; length at maturity > 80 cm; maximum length = 180-200 cm; maximum age ≈ 25 years.

STOCK SIZE/STATUS: Anglerfish in subareas 1 and 2 have never been assessed quantitatively and besides the presented catch, catch per unit effort (CPUE) and catch mean length series, it is impossible to describe the historical stock development. Catches and catch rates have decreased by more than 50% in recent years, but a small improvement is expected for 2019 due to successful recruitment (ICES, 2019). Catch rates, i.e. about 0.3 kg per gillnet soaking day, are currently, however, at about the same level as the catch rates reported after the "Klondyke" fishing period during 1992-1994 in the southern area of the ICES Division 2a. WKAngler recommends improving the standardization of the commercial CPUE index. There is evidence of spatiotemporal changes in distribution that should be accounted for in index standardization. Four methods approved by ICES for calculating maximum sustainable yield (MSY) reference points should be explored (ICES, 2018).

OTHER STRESSORS: The anglerfish stock in ICES subareas 1 and 2 is experiencing no stress other than fishing, including bycatches of juveniles in some of the North Sea trawl fisheries. The stock is hence experiencing no more than one known stressor.

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 Anglerfish (*Lophius piscatorius*) 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.

Anglerfish (*Lophius piscatorius*) in ICES subareas 1 and 2

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	1	3	1	0	**2.0**		
Adult Mobility	0	5	0	0	**2.0**		
Dispersal of Early Life Stages	4	1	0	0	**1.2**		
ELH Survival and Settlement Requirements	2	3	0	0	**1.6**		
Complexity in Reproductive Strategy	0	4	1	0	**2.2**		
Spawning Cycle	0	2	3	0	**2.6**		
Sensitivity to Temperature	0	1	4	0	**2.8**		
Sensitivity to Ocean Acidification	1	3	1	0	**2.0**		
Population Growth Rate	0	0	0	5	**4.0**		
Stock Size/Status	0	0	3	2	**3.4**		
Other Stressors	5	0	0	0	**1.0**		
Grand mean					**2.09**		
Grand mean SD					**0.91**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	2	2	1	0	**1.8**	3	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	
O_2 (Surface)	3	2	0	0	**1.4**	1	-1
pH (Surface)	3	2	0	0	**1.4**	1	-1
Gross Primary Production	3	2	0	0	**1.4**	1	1
Gross Secondary Production	2	2	1	0	**1.8**	2	1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.56**		
Grand mean SD					**0.22**		
Accumulated Directional Effect					**–**		**2.2**

***Accumulated Directional Effect*: POSITIVE**	**2.2**

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