ATLANTIC WOLFFISH

Stock name: Atlantic wolffish
Latin name: *Anarhichas lupus*
Geographical area: Norwegian and Barents Seas (ICES subareas 1 and 2)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: The Atlantic wolffish (*Anarhichas lupus*, Anarhichadidae) prefers more coastal areas and inhabits shallower depths. *A. lupus* is found from near-shore to depths of more than 900 m (Kulka et al., 2008; Kulka & Simpson, 2004), but seldomly > 350 m. Four relatively isolated groups of Atlantic wolffish are present in the Barents Sea and adjacent waters: off the northwestern coast of Norway, around Bear Island, in waters of the Svalbard archipelago, and off the coast of the Kola Peninsula (Shevelev & Johannesen, 2011). Each group is linked to different spawning grounds (Barsukov, 1959). The widespread distribution over large parts of the Barents Sea and along the Norwegian coast as well as in fjords suggests that the stock is a habitat generalist. However, the availability of echinoderm prey and a preferred area for possibilities to guard its spawn may limit preferred habitats. Hot spots for Atlantic wolffish and spotted wolffish (*Anarhichas* minor, Anarhichadidae) occur in areas where a greater diversity of relief and habitats are found. They were associated with intermediate depths, coarse sediments and rock outcrops, and lower salinities and temperatures than for Northern wolfish.

PREY SPECIFICITY: The stock feeds on a wide variety of prey species but prefers echinoderms (sea urchins and brittle stars), molluscs, clams, and crustaceans. Piscivorous feeding increases with age (Shevelev & Johannesen, 2011).

SPECIES INTERACTION: In their habitats, wolffish interact with other species both as prey and as predator. Continued research on wolffish diet and species assemblages may improve our understanding of important ecological requirements of wolffish. At a certain size, Atlantic wolffish fry descend to the sea floor, and at this time the juveniles are prone to predation (Shevelev & Johannesen, 2011). The stock is somewhat influenced by the feeding activity of competing stocks and predators in the same area. There exists little knowledge and few analyses on this, but it is likely that both haddock and cod, as well as spotted wolffish and northern wolffish share to some extent the same prey groups. Top-down control by wolffish regulates urchin and crab population variability.

ADULT MOBILITY: The Atlantic wolffish is much more stationary than the other two wolffish species (*Anarhichas denticulatus*, *Anarhichas minor*, Anarhichadidae) (COSEWIC, 2012; Nedreaas, 2018; Shevelev & Johannesen, 2011). The stock has site-dependent adults capable of moving from one site to another if necessary, especially for feeding and spawning (Shevelev & Johannesen, 2011). Studies about habitat-species association have been done at the centre of wolffish distribution (Grand Banks to Labrador Shelf) (Kulka & Simpson, 2004) and in the Gulf of St Lawrence (Dutil et al., 2014).

DISPERSAL OF EARLY LIFE STAGES: The eggs with a diameter of 4-6 mm constitute up to 25-35% of female body weight. The eggs mature almost simultaneously, and the batch is attached to rocky grounds in a ball-shaped deposit (Shevelev & Johannesen, 2011). Males guard the eggs until they hatch. The development lasts 9-10 months until hatching or 800 to 1,000 degree-days (Falk-Petersen & Hansen, 2003). Yolk sac larvae hatch with a size of >20 mm (Wiseman, 1997) and remain close to the bottom until yolk sac absorption. Later staged larvae migrate to near-surface water layers and drift with currents, but are generally not far dispersed from origin (McRuer et al., 2000). Larvae feed and live pelagically for several weeks and settle in benthic environments at 4-6 cm length (Barsukov, 1959; Falk-Petersen et al., 1999; Shevelev, 1994).

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: See above; wolffish have internal fertilization and spawns fertilized large eggs in ball-shaped deposits (Shevelev & Johannesen, 2011) on the substrate which are guarded by the male until they hatch.

COMPLEXITY IN REPRODUCTIVE STRATEGY: An important feature is the internal egg fertilization and an advanced embryonic development inside the egg, leading to hatching of almost juvenile organisms, able to feed externally (Pavlov & Moksness, 1994). Three characteristics are suggested with regards to complexity in reproductive strategy, i.e. suitable substrate for depositing the eggs, a temperature range between 3-8 °C, and local suitable prey for the larvae.

SPAWNING CYCLE: The Atlantic wolffish spawns near the coast, in fjords and bays at depths between 50 and 130-150 m from July to October, with a peak in August (Shevelev & Johannesen, 2011). Among the Barents Sea fish species, individual absolute fecundity is the lowest whereas relative fecundity (per unit body weight) is the highest. After the spawning event larvae hatch the following year, between March and June (Barsukov, 1959; Gusev & Shevelev, 1997; Shevelev, 1984; Sokolov & Shevelev, 1994). In captivity, Atlantic wolffish spawned from December to March. The spawning of fertilized eggs lasts for several months, but there it seems that the individual fish spawn all at once (Kvalsund, 1990; Shevelev & Johannesen, 2011). The reproductive cycle appears to last over two years. Behavioural studies indicate mating wolffish with internal egg fertilization.

SENSITIVITY TO TEMPERATURE: The lower limit for initial development of wolffish eggs until the beginning of blood circulation in embryo is at 3 °C (Pavlov & Moksness, 1994), and the upper temperature limit 2 weeks before and after hatching is limited to 7-8 °C. Optimal temperature (T_{opt}) for growth decreases with increasing fish size, as T_{opt} for juveniles (10-500 g) is 8 °C and declines further to 4-6 °C for larger fish, including broodstock (Kime & Tveiten, 2002; Lundamo, 1999; Moksness, 1994). However, adults are not particularly demanding and may live at temperature ranging from 1 to 10 °C in the Northeast Atlantic (Beese & Kandler, 1969).

SENSITIVITY TO OCEAN ACIDIFICATION: The direct effect of ocean acidification (OA) on Atlantic wolffish is not well understood. The stock is currently dependent on sensitive taxa as food (copepods at larval and juvenile stages, later on macro- and megabenthos such as mollusks, echinoderms, and crustaceans), but should be able to prey also on fish as adults when necessary. Its general deep habitats as adults, usually 10-350 (900) m, may cause a moderate exposure to acidification. The fact that Atlantic wolffish inhabits coastal and inner fjord areas may increase the species risks to environmental pollution and OA.

POPULATION GROWTH RATE: von Bertalanffy K <= 0.10; age at maturity > 5 years; maximum length = 125 cm; maximum age = 20 years.

STOCK SIZE/STATUS: The Russian Federal Research Institute of Fisheries and Oceanography VNIRO and its polar branch PINRO described the development of all three wolffish species in the Barents Sea during 1979-2016 (van der Meeren & Prozorkevich, 2019). The stock biomass of Atlantic wolffish in the Barents Sea increase after 2002. The IMR in Norway is monitoring the Atlantic wolffish in the same area in the southern Barents Sea since 1981. Results from this monitoring program indicate a clear increase of Atlantic wolffish in 2012-2017 compared to the long-term average in 1981-2003. These two-timeseries together have been used as a proxy of stock status and biomass/biomass maximum sustainable yield which hence have been evaluated as low to moderate vulnerability. Mean catch per unit effort (CPUE in kg) per 100 gillnets days during 2007-2017 has been calculated for several coastal fishing vessels fishing from south to north in ICES Subarea 1 and 2. These CPUEs decreased 33% between 2007-2017 indicating a stock status with high vulnerability to fisheries.

OTHER STRESSORS: The Atlantic wolffish is experiencing limited stress other than fishing, including tourist fishing. Environmental stress, especially in coastal fjord areas where the fish may be particularly prone to pollution, could increase the stress on the local populations directly or indirectly by destroying key habitats and key prey species like echinoderms and shellfish. The stock is considered to experience no more than two known stressors.

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 Atlantic wolffish (*Anarhichas lupus*) 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.

Atlantic wolffish (*Anarhichas lupus*) 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	0	4	1	0	**2.2**		
Species Interaction	0	5	0	0	**2.0**		
Adult Mobility	0	5	0	0	**2.0**		
Dispersal of Early Life Stages	0	5	0	0	**2.0**		
ELH Survival and Settlement Requirements	2	3	0	0	**1.6**		
Complexity in Reproductive Strategy	0	2	3	0	**2.6**		
Spawning Cycle	0	2	3	0	**2.6**		
Sensitivity to Temperature	0	3	2	0	**2.4**		
Sensitivity to Ocean Acidification	0	3	2	0	**2.4**		
Population Growth Rate	0	0	2	3	**3.6**		
Stock Size/Status	0	3	2	0	**2.4**		
Other Stressors	0	5	0	0	**2.0**		
Grand mean					**2.23**		
Grand mean SD					**0.57**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	3	2	0	0	**1.4**	2	1
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	4	1	0	0	**1.2**	1	1
Gross Secondary Production	4	1	0	0	**1.2**	1	1
Sea Ice Abundance	3	2	0	0	**1.4**	1	1
Grand mean					**1.33**		
Grand mean SD					**0.10**		
Accumulated Directional Effect					**–**		**2.4**

***Accumulated Directional Effect*: POSITIVE**	**2.4**

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