SPOTTED WOLFFISH

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

HABITAT SPECIFICITY: The spotted wolffish (*Anarhichas minor*, Anarhichadidae) migrates hundreds of kilometres between spawning, grazing and wintering areas (COSEWIC, 2012; Fisheries and Oceans Canada, 2018; Nedreaas, 2018; Shevelev & Johannesen, 2011). All wolffishes in northern waters have a seasonal grazing cycle. In the period October-May, they change their teeth and suspend feeding. The widespread distribution in the Barents Sea suggests that the stock is a habitat generalist, but the preference for echinoderms as prey may define more specifically preferred habitats. Hot spots for spotted and Atlantic wolffish occurred in areas where a greater diversity of relief and habitats was found. They were associated with intermediate depths, coarse sediments and rock outcrops, and lower salinities and temperatures than for northern wolffish. However, spotted wolffish lives in deeper water (50-250 m) than Atlantic wolffish where temperature and salt content are nearly constant (Shevelev & Johannesen, 2011).

PREY SPECIFICITY: The stock can feed on a wide variety of prey species but prefers echinoderms (sea urchins and brittle stars), molluscs, clams, and crustaceans. Fish diet becomes more important with increasing age (Shevelev & Johannesen, 2011).

SPECIES INTERACTION: In their habitats, wolffish interact with other species both as prey and as predator (Fisheries and Oceans Canada, 2018; Shevelev & Johannesen, 2011). Continued research on wolffish diet and species assemblages may improve our understanding of important ecological requirements of wolffish. The stock is somewhat influenced by the feeding activity of competing stocks and predators in the same area. Little knowledge exists, but it is likely that both haddock and cod, as well as Atlantic wolffish and northern wolffish share the same prey. Wolffish is assumed to be a main driver of urchin and crab populations.

ADULT MOBILITY: The stock has site-dependent adults capable of moving from one site to another if necessary. Work about habitat association has 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). Due to their widespread distribution, diverse habitat preferences, and lack of particular spawning or feeding aggregations spatial closures are considered to be an ineffective method to reduce wolffish by-catch at this time.

DISPERSAL OF EARLY LIFE STAGES: The eggs with a diameter of 4-6 mm of the three wolffish species 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. 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 with 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 on the substrate which are guarded by the male until they hatch (COSEWIC, 2012; Shevelev & Johannesen, 2011).

COMPLEXITY IN REPRODUCTIVE STRATEGY: An important feature is the internal fertilization and an advanced embryonic development inside the egg, leading to hatching of almost juvenile organisms, able to feed externally (Pavlov & Moksness, 1994). The lower limit for initial development of wolffish eggs until the beginning of blood circulation should be 3 °C, and the upper temperature limit 2 weeks before and after hatching should be no more than 7-8 °C (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. The female matures earlier at a smaller size than the male fish.

SPAWNING CYCLE: The reproductive cycle appears to last over two years. Behavioural studies indicate that the wolffish mates by means of internal fertilization. There are many indications that the individual fish spawns all at once. Spawning of spotted wolffish takes place in the southwestern part of the Barents Sea shelf from June to September, with a peak in July (Barsukov, 1959; Beese & Kandler, 1969; Mazhirina, 1988; Østvedt, 1963; Shevelev, 1984, 1988, 1994).

SENSITIVITY TO TEMPERATURE: Optimal temperature (T_{opt}) for growth and survival in the earliest juvenile phase (up to 60 days post hatching, weight 2-3 g) is at 10.3 °C (Hansen & Falk-Petersen, 2002). Optimal temperature for subsequent growth decreases with increasing fish weight, 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). Spotted wolffish are widespread, found at depths of 25 to 750 m and water temperatures between 2 and 5 °C.

SENSITIVITY TO OCEAN ACIDIFICATION: The direct effect of ocean acidification on spotted wolffish is not well understood. The stock is dependent on sensitive taxa as food (copepods as juveniles, and molluscs, echinoderms, and crustaceans as adults), but should be able to increase fish diet when necessary. Its general deep habitats as adults, usually 100-400 m, may cause a moderate exposure to acidification.

POPULATION GROWTH RATE: von Bertalanffy K <= 0.10; age at maturity > 5 years; maximum length = 180 cm.

STOCK SIZE/STATUS: VNIRO-PINRO (Russia) has followed the development of all three wolffish species in the Barents Sea during 1979-2016 (Grekov, 2018; van der Meeren & Prozorkevich, 2019). The abundance of spotted wolffish has, according to Russian survey data, increased, and is now on the 1980s level. The Institute of Marine Research (Norway) has monitored the wolffishes in the same area in the southern Barents Sea since 1981. Results from these winter surveys (2012-2017) show that the abundance of spotted wolffish is at the same level as the long-term average (1981-2003). These two-timeseries together have been used as a proxy of stock status and biomass/biomass maximum sustainable yield (B/B_{MSY}) which has been evaluated to be moderate.

OTHER STRESSORS: The spotted wolffish stock is experiencing no known stress other than fishing. 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 Spotted wolffish (*Anarhichas minor*) 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.

Spotted wolffish (*Anarhichas minor*) 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	3	2	0	**2.4**		
Sensitivity to Temperature	0	0	5	0	**3.0**		
Sensitivity to Ocean Acidification	0	2	3	0	**2.6**		
Population Growth Rate	0	0	0	5	**4.0**		
Stock Size/Status	0	5	0	0	**2.0**		
Other Stressors	5	0	0	0	**1.0**		
Grand mean					**2.20**		
Grand mean SD					**0.77**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	0
Temperature 100 m	0	2	2	1	**2.8**	2	1
Temperature 500 m	0	0	0	0		N/A	0
Bottom Temperature	0	0	0	0		N/A	0
O_2 (Surface)	4	1	0	0	**1.2**	2	-1
pH (Surface)	3	2	0	0	**1.4**	1	-1
Gross Primary Production	4	1	0	0	**1.2**	2	0
Gross Secondary Production	4	1	0	0	**1.2**	2	1
Sea Ice Abundance	2	2	1	0	**1.8**	2	1
Grand mean					**1.60**		
Grand mean SD					**0.63**		
Accumulated Directional Effect					**–**		**3.2**

***Accumulated Directional Effect*: POSITIVE**	**3.2**

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