NORTHERN WOLFFISH

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

HABITAT SPECIFICITY: The northern wolffish (*Anarhichas denticulatus*, Anarhichadidae) distribution is in the open areas of the North Atlantic and the offshore region of the continental shelf (COSEWIC, 2012; Fisheries and Oceans Canada, 2018; Nedreaas, 2018; Shevelev & Johannesen, 2011). The northern wolffish occurs in bathypelagic waters and has been observed as 1,325 m depth (corresponding to the deepest record for any of the wolffish species) (Shevelev & Johannesen, 2011). The northern wolffish is mostly living in the free water column, sometimes ascending to the surface (Barsukov, 1959; Shevelev, 1982, 1984, 1988). Ascending larvae are probably drifting with currents to the open part of the Norwegian Sea. The growing juveniles redistribute from the west to the Svalbard archipelago, the Norwegian exclusive economic zone, and further to the east of the Barents Sea, taking advantage of countercurrents (Shevelev & Kuzmichev, 1990). The spread distribution in pelagic waters over a large range suggests that the stock is a habitat generalist.

PREY SPECIFICITY: The northern wolffish preys on diverse food items such as ctenophores, jellyfish, fish (especially pelagic fish including mesopelagic) and bottom invertebrates with soft skeleton (sea urchins and brittle stars) (Shevelev & Johannesen, 2011).

SPECIES INTERACTION: Continued research on wolffish diet and species assemblages may improve our understanding of important ecological requirements of wolffish in general. Little knowledge exists on species interactions, but it is likely that the stock due to its wide pelagic distribution and long migrations is little influenced by interspecific interactions (Fisheries and Oceans Canada, 2018; Shevelev & Johannesen, 2011).

ADULT MOBILITY: The stock is site dependent during spawning but highly mobile at other times. The northern wolffish undertakes extensive seasonal migrations (beyond the waters of the Barents Sea shelf) (Barsukov, 1959; Shevelev, 1982, 1984, 1988). Its spawning grounds are located on the continental slope of the Barents Sea/Norwegian Sea but are not accurately known. 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 northern wolffish by-catch at this time (Dutil et al., 2014; Fisheries and Oceans Canada, 2018; Kulka et al., 2008).

DISPERSAL OF EARLY LIFE STAGES: The eggs of northern wolffish are large (4-6 mm in diameter). However, eggs have been reported to be up to 7-8 mm in diameter (Barsukov, 1959). The eggs ripen almost simultaneously and the whole amount is laid directly on the stony grounds in ball-shaped deposits on the continental slope of the Barents Sea/Norwegian Sea at depths of over 400 m. As for other wolffish species, the eggs are guarded by the male until they hatch. The incubation period is 9-10 months or 800 to 1,000 degree-days (Falk-Petersen & Hansen, 2003). The larvae hatch as well-developed individuals (25-26 mm) with a relatively small yolk sac which is resorbed after 3-4 weeks (Shevelev & Kuzmichev, 1990). They feed and live mainly pelagic. Since the larvae are hatched in a rather strong sea current area on the continental slope and also stay long in the pelagic, it is expected that larvae are dispersed >100 km from spawning locations.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: Northern wolffish has internal fertilization and spawns fertilized large eggs in ball-shaped deposits on rocky bottom which are guarded by the male until they hatch. Larvae are assumed to disperse far from the spawning locations.

COMPLEXITY IN REPRODUCTIVE STRATEGY: An important feature is the internal fertilization in wolffish and a very advanced period of development inside the egg envelope leading to hatching of organisms ready for external feeding (Pavlov & Moksness, 1994). Three characteristics are suggested with regards to complexity in reproductive strategy, i.e. a suitable substrate for depositing the eggs, an optimal temperature range between 1-2 °C (1-6 °C total range), and local suitable feed for the hatched larvae (because of the short period of internally energy reserves due to the very small yolk sac after hatching).
SPAWNING CYCLE: Spawning of northern wolffish is reported taking place from April to October, with a peak in June-July at depths of over 400 m (Barsukov, 1959; Mazhirina, 1988; Shevelev, 1982; Shevelev & Kuzmichev, 1990). In the western Atlantic the spawning time is reported to be late in the year. There are many indications that the individual female spawns all at once. The reproductive cycle appears to last over two years. The female matures earlier and at a smaller size than the male fish.

SENSITIVITY TO TEMPERATURE: Northern wolffish is not particularly requiring deep depths, but the preferred temperatures range narrow habitat specificities. In the Northeast Atlantic, northern wolffish lives in a temperature range of 1.0-6.3 °C, mostly between 1-2 °C (Beese & Kandler, 1969), within a reported depth range of 70-1,325 m. Highest catch rates are reported at 100-300 m.

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

POPULATION GROWTH RATE: The northern wolffish is the largest of the wolffish species, and has the highest growth rate (Barsukov, 1959): von Bertalanffy K <= 0.10; length at maturity > 80 cm; 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; Nedreaas, 2018; van der Meeren & Prozorkevich, 2019). From 1979 to 1985, there was a clear decline in the abundance of northern wolffish after a ten-year period of intensive fishing by the Soviet trawler fleet. Until 2000, the Northern wolffish stock remained stable, but was then reduced, before again showing signs of improvement in recent years. The whole timeseries shows, however, that the current abundance level is only about 40% of the abundance level around 1980. The Institute of Marine Research 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 northern wolffish in recent years is around 85% of the long-term average for 1981-2003. The Russian timeseries, i.e. the longest of the two, has been used as a proxy of stock status and biomass/biomass maximum sustainable yield (B/B_{MSY}) which points to a very high stress level from fishing. The fact that the decrease has stopped and that the stock has increased in recent years may moderate this evaluation of the stock status.

OTHER STRESSORS: The northern 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 Northern wolffish (*Anarhichas denticulatus*) 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.

Northern wolffish (*Anarhichas denticulatus*) 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	4	1	0	0	**1.2**		
Adult Mobility	0	5	0	0	**2.0**		
Dispersal of Early Life Stages	2	3	0	0	**1.6**		
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	3	2	0	**2.4**		
Sensitivity to Ocean Acidification	0	2	3	0	**2.6**		
Population Growth Rate	0	0	0	5	**4.0**		
Stock Size/Status	0	0	2	3	**3.6**		
Other Stressors	5	0	0	0	**1.0**		
Grand mean					**2.11**		
Grand mean SD					**0.94**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	0
Temperature 100 m	0	0	3	2	**3.4**	3	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**	1	-1
pH (Surface)	0	2	3	0	**2.6**	2	-1
Gross Primary Production	5	0	0	0	**1.0**	1	0
Gross Secondary Production	5	0	0	0	**1.0**	1	1
Sea Ice Abundance	0	2	2	1	**2.8**	1	1
Grand mean					**2.00**		
Grand mean SD					**1.06**		
Accumulated Directional Effect					**–**		**3.4**

***Accumulated Directional Effect*: POSITIVE**	**3.4**

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