SPURDOG

Stock name: Spurdog
Latin name: *Squalus acanthias*
Geographical area: Northeast Atlantic (ICES subareas 1-10, 12 and 14)
Expert: Claudia Junge, Ole Thomas Albert, Hannes Höffle
Date: 23 March 2020

Stock Sensitivity Attributes

HABITAT SPECIFICITY: Spurdog (*Squalus acanthias*, Squalidae) is a coastal shark in temperate and boreal waters of the Atlantic and Pacific Oceans, mainly found in depths between 10 and 200 m (but has been recorded to depths of 900 m) (Compagno, 1984; Fordham et al., 2016). In the Northeast Atlantic, spurdogs are distributed widely in shelf seas and occur from Iceland and the Barents Sea southwards to Northwest Africa and the Mediterranean Sea, although most common north of the Bay of Biscay. The southernmost extent in the Northeast Atlantic is difficult to judge, as there is a mixed occurrence with *Squalus blainville* and therefore often only mixed catch data (ICES, 2019). Primarily epibenthic, they are not known to associate with any particular habitat (Fordham et al., 2016). Vertical monitoring suggests distinct diel migration patterns while this species is considered absent from previously assumed benthic habitat (Carlson et al., 2014). Usually coastal and demersal, they migrate north and south as well as near shore and offshore in 7 to 15 °C water (Compagno, 1984). Mating occurs in offshore areas in autumn and winter, whilst pupping in offshore areas in winter (for Northwest (NW) Atlantic population, not known for Northeast Atlantic) (Burgess, 2002; Stehlik, 2007). Spurdog can tolerate brackish water but prefers ocean conditions (Burgess, 2002; Stehlik, 2007).

PREY SPECIFICITY: Juvenile spurdog feeds on ctenophores, squid and krill. Subadults forage on bivalves and decapods, especially shrimps. Adult spurdog mostly feed on small schooling fish (herring, mackerel), but also molluscs, crustaceans, jellyfish, and solitary fish as flatfish and haddock (Burgess, 2002; Stehlik, 2007).

SPECIES INTERACTION: Predators include larger sharks including conspecifics, cod, hake, monkfish, striped bass, and possibly whales, seals and dolphins (Burgess, 2002; Stehlik, 2007). They compete for food with other mesopredators.

ADULT MOBILITY: Analyses of tagging studies suggest a single Northeast Atlantic stock, although transatlantic migrations are observed (Hammond & Ellis, 2005; ICES, 2019). Spurdog forms schools based on size and/or sex (Burgess, 2002). They exhibit seasonal migrations to feeding, mating and pupping grounds. There seem to be resident and migratory individuals in a population, which could be attributed to mating activities and according migration behaviour (Burgess, 2002; Thorburn et al., 2015). Females are thought perform more restricted movements. Females have been shown to migrate from deep to shallow water as pregnancy progresses (Thorburn et al., 2015). Observations on vertical migration behaviour suggest distinct diel patterns (Carlson et al., 2014).

DISPERSAL OF EARLY LIFE STAGES: The spurdog does not have planktonic early life stages.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: As an elasmobranch, this sensitivity attribute has marginal relevance.

COMPLEXITY IN REPRODUCTIVE STRATEGY: Spatial and temporal complexity due to the following reproductive behaviours: 1. seasonal reproduction (i.e. initiation with environmental cues) and 2. migration to specific mating and pupping areas. In addition, females have a continuous asynchronous reproductive cycle (Burgess, 2002; Carlson et al., 2014; Hammond & Ellis, 2005; Stehlik, 2007; Thorburn et al., 2015).

SPURDOG

SPAWNING CYCLE: The spurdog is an aplacental viviparous species with a gestation duration of 18-22 months. The reproductive cycle completes in almost two years, one of the longest gestation periods of any living vertebrate (Burgess, 2002; Jones & Ugland, 2001; Northeast Fisheries Science Center (NEFSC), 2006).

SENSITIVITY TO TEMPERATURE: They migrate north and south as well as near shore and offshore in 6 to 15 °C water; they seem to prefer temperatures between 6 and 10 °C (Compagno, 1984; Shepherd et al., 2002). Changes in temperature in the range of those projected under various climate scenarios are unlikely to have a significant impact on the species.

SENSITIVITY TO OCEAN ACIDIFICATION: It remains unclear to what extent there will be indirect effects of ocean acidification (OA) through the food web for higher-trophic level species. Case studies suggest that OA will lead to a decline in prey that subsequently impacts higher trophic levels (Olsen et al., 2018). Indirect food web effects of OA have been shown particularly strong for some mammal, shark and demersal fish functional groups with modelled declines by more than 50% (Kroeker et al., 2013; Olsen et al., 2018). It is assumed that active animals have a higher capacity for buffering pH changes, and that the tolerance of CO_2 concentrations by marine fish appears to be very high (Fabry et al., 2008). As spurdog is an active, highly mobile species, it is assumed that they can tolerate changes in CO_2 and buffer pH changes. This is, however, with respect to tolerance and is not taking potential negative behavioural and physiological effects into consideration. Those types of negative effects on e.g. hunting behaviour and growth have been shown for other predatory shark species and were more pronounced when coupled with other stressors like increasing temperatures (Dixson et al., 2015; Pistevos et al., 2015, 2017; Rosa et al., 2017). The North Sea and the Norwegian Sea are predicted to decline in pH between 0.8 and 1.2 by 2046 (NORWECOM.E2E). As spurdogs migrate between vital areas of e.g. mating and pupping, they will be exposed to a variety of OA levels.

POPULATION GROWTH RATE: The species matures late and has a very long reproductive cycle and is hence very vulnerable to overharvesting (Albert et al., 2019; Hammond & Ellis, 2005; ICES, 2019).

STOCK SIZE/STATUS: Current stock size is estimated at 24% of primordial biomass levels (ICES, 2019). There is currently no targeted fishery for spurdog in the Northeast Atlantic, but previous high fishing pressure caused a collapse of the stock. According to the latest assessment by ICES, the stock has not been overfished since 2005 and SSB is slowly increasing, expecting >20 years to reach a desired level (MSY $B_{trigger}$, i.e. a biomass reference point below which a cautious response is triggered within the ICES maximum sustainable yield framework) (ICES, 2019). However, the potential for a faster recovery of the spurdog stock has been recently suggested (Albert et al., 2019), based on data from Norwegian waters.

OTHER STRESSORS: The principal threat to this species worldwide is over-exploitation, by target and bycatch fisheries (Fordham et al., 2016). This is a valuable commercial species in many parts of the world, mainly found in bottom trawls, gillnets, line gear, and by rod and reel fisheries. There are potential impacts on spurdog associated with habitat loss and degradation. Coastal development, pollution, dredging and bottom trawling affect coastal or benthic habitats of spurdog (Atlantic States Marine Fisheries Commission (ASMFC), 2008; Fordham et al., 2016).

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 Spurdog (*Squalus acanthias*) in ICES subarea 4 and division 3.a. 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.

Spurdog (*Squalus acanthias*) in ICES subarea 4 and division 3.a

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	3	2	0	0	**1.4**		
Prey Specificity	5	0	0	0	**1.0**		
Species Interaction	3	2	0	0	**1.4**		
Adult Mobility	2	3	0	0	**1.6**		
Dispersal of Early Life Stages	0	0	0	5	**4.0**		
ELH Survival and Settlement Requirements	5	0	0	0	**1.0**		
Complexity in Reproductive Strategy	1	3	1	0	**2.0**		
Spawning Cycle	0	0	4	1	**3.2**		
Sensitivity to Temperature	1	3	1	0	**2.0**		
Sensitivity to Ocean Acidification	0	2	1	2	**3.0**		
Population Growth Rate	0	0	3	2	**3.4**		
Stock Size/Status	0	0	3	2	**3.4**		
Other Stressors	1	3	1	0	**2.0**		
Grand mean					**2.26**		
Grand mean SD					**1.01**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	0	3	2	0	**2.4**		1
Temperature 500 m	0	0	0	0		N/A	
Bottom Temperature	0	0	0	0		N/A	
O_2 (Surface)	4	1	0	0	**1.2**		-1
pH (Surface)	4	1	0	0	**1.2**		-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					**1.56**		
Grand mean SD					**0.50**		
Accumulated Directional Effect					**–**		**3.0**

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

References

Albert, O. T., Junge, C., & Myrlund, M. K. (2019). Young mums are rebuilding the spurdog stock (*Squalus acanthias* L.) in Norwegian waters. *ICES Journal of Marine Science*, *76*(7), 2193–2204.

Atlantic States Marine Fisheries Commission (ASMFC). (2008). *Management Report of the Atlantic States Marine Fisheries Commission* (No. 46; p. 172). Atlantic States Marine Fisheries Commission (ASMFC). . http://www.asmfc.org/uploads/file/interstateFMPforAtlanticCoastalSharks.pdf

Burgess, G. (2002). Spiny Dogfish/ *Squalus acanthias* Linnaeus 1758. In B. Collette & G. Klein-MacPhee (Eds.), *Fishes of the Gulf of Maine* (3rd ed., pp. 54–57). Smithsonian Institution Press.

Carlson, A. E., Hoffmayer, E. R., Tribuzio, C. A., & Sulikowski, J. A. (2014). The use of satellite tags to redefine movement patterns of spiny dogfish (*Squalus acanthias*) along the US East coast: Implications for

fisheries management. *PLoS One*, *9*(7), e103384.
Compagno, L. J. (1984). *Sharks of the World: An Annotated and Illustrated Catalogue of Shark Species Known to Date* (Vol. 4). FAO Fisheries Synopsis.
Dixson, D. L., Jennings, A. R., Atema, J., & Munday, P. L. (2015). Odor tracking in sharks is reduced under future ocean acidification conditions. *Global Change Biology*, *21*(4), 1454–1462.
Fabry, V. J., Seibel, B. A., Feely, R. A., & Orr, J. C. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, *65*(3), 414–432.
Fordham, S., Fowler, S., Coelho, R., Goldman, K., & Francis, M. (2016). Squalus acanthias*. The IUCN Red List of Threatened Species 2016: E.T91209505A2898271.* The IUCN Red List of Threatened Species 2016.
Hammond, T., & Ellis, J. (2005). Bayesian assessment of Northeast Atlantic spurdog using a stock production model, with prior for intrinsic population growth rate set by demographic methods. *Journal of Northwest Atlantic Fishery Science*, *35*, 299–308.
ICES. (2019). *Working Group on Elasmobranch Fishes (WGEF)* (ICES Scientific Reports 1 : 25; p. 964). ICES.
Jones, T. S., & Ugland, K. I. (2001). Reproduction of female spiny dogfish, *Squalus acanthias*, in the Oslofjord. *Fishery Bulletin-National Oceanic and Atmospheric Administration*, *99*(4), 685–690.
Kroeker, K. J., Kordas, R. L., Crim, R., Hendriks, I. E., Ramajo, L., Singh, G. S., Duarte, C. M., & Gattuso, J. (2013). Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. *Global Change Biology*, *19*(6), 1884–1896.
Northeast Fisheries Science Center (NEFSC). (2006). *43rd Northeast Regional Stock Assessment Workshop (43rd SAW): 43rd SAW assessment report* (Ref Doc 06-25; p. 400). Northeast Fisheries Science Center (NEFSC).
Olsen, E., Kaplan, I. C., Ainsworth, C., Fay, G., Gaichas, S., Gamble, R., Girardin, R., Eide, C. H., Ihde, T. F., Morzaria-Luna, H. N., & Johnson, K. (2018). Ocean futures under ocean acidification, marine protection, and changing fishing pressures explored using a worldwide suite of ecosystem models. *Frontiers in Marine Science*, *5*, 64.
Pistevos, J. C., Nagelkerken, I., Rossi, T., & Connell, S. D. (2017). Antagonistic effects of ocean acidification and warming on hunting sharks. *Oikos*, *126*(2), 241–247.
Pistevos, J. C., Nagelkerken, I., Rossi, T., Olmos, M., & Connell, S. D. (2015). Ocean acidification and global warming impair shark hunting behaviour and growth. *Scientific Reports*, *5*(1), 16293.
Rosa, R., Rummer, J. L., & Munday, P. L. (2017). Biological responses of sharks to ocean acidification. *Biology Letters*, *13*(3), 20160796.
Shepherd, T., Page, F., & Macdonald, B. (2002). Length and sex-specific associations between spiny dogfish (*Squalus acanthias*) and hydrographic variables in the Bay of Fundy and Scotian Shelf. *Fisheries Oceanography*, *11*(2), 78–89.
Stehlik, L. L. (2007). *Essential fish habitat source document. Spiny dogfish,* Squalus acanthias*, life history and habitat characteristics* (NE 203; p. 44). NOAA Technical Memorandum NMFS.
Thorburn, J., Neat, F., Bailey, D., Noble, L., & Jones, C. (2015). Winter residency and site association in the Critically Endangered North East Atlantic spurdog *Squalus acanthias*. *Marine Ecology Progress Series*, *526*, 113–124.