Stock name: North Sea sprat
Latin name: *Sprattus sprattus*
Geographical area: Skagerrak, Kattegat and North Sea (ICES subarea 4 and division 3.a)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: The sprat (*Sprattus sprattus*, Clupeidae) is a small and pelagic clupeid preying on zooplankton (Peck et al., 2012). The species distribution is broad and ranges from the Black and Mediterranean Seas in the south of European water to the European Atlantic shelf, including the North and Baltic Seas (Muus et al., 1999). Sprat tolerates a wide range of salinities and is abundant in estuarine habitats (Araújo et al., 2000). As a pelagic species, hydrographic conditions strongly affect its distribution which, together with its abundance, experience inter-annual large variation. Larvae are most abundant close to tidal mixing fronts (Valenzuela & Vargas, 2002).

PREY SPECIFICITY: Sprat is an obligate particulate feeder and the growth might be strongly affected by variability in the abundance of optimal sizes of prey (Peck et al., 2012). In large juvenile and adult sprat guts, the most common prey are copepods (*Temora longicornis*, *Pseudocalanus acuspes* (Clausocalanidae), *Acartia* spp.) along with cladocerans (*Evadne nordmanni* (Podonidae), *Bosmina longispina maritima* (Bosminidae), *Podon* spp.) (Bernreuther, 2007). Sprat can also prey on fish eggs, e.g. plaice eggs and larvae (Ellis & Nash, 1997). While larvae prey on crustacean larvae, diatoms and copepods (Blaxter & Hunter, 1982; Russell, 1976), individuals after metamorphosis (32-41 mm) (Russell, 1976), feed on larger planktonic organisms including cladocerans, *Oikopleura* spp., bivalve larvae, mysids, and euphausiids (De Silva, 1973).

SPECIES INTERACTION: Currently, several species such as the European anchovy, sardine, and herring, coexist with sprat in the North Sea. In the German Bight where sprat and sardine larvae co-occurred, the analyses of the gut content revealed a high degree of diet overlap but the potential competition for prey is minimized by different spatial distribution of these two species (Voss et al., 2009). However, the feeding abilities increasing with age may intensify the competition at juvenile and adult stages. In these life stages, a competitive advantage over sprat is provided to sardine, anchovy, and Atlantic herring due to their ability to swich between feeding modes (filter and particulate) and to prey on a wider range of organism sizes and types (Raab et al., 2011), especially when these species experience poor feeding conditions (e.g. low zooplankton concentrations and/or prey fields characterized by relatively small zooplankton). Sprat may also experience intra-specific competition (Maes et al., 2005; Peck et al., 2012). For diving seabirds and many commercially important predatory fish species (e.g. the larger gadoids), sprat represents an important prey (Daan et al., 1990).

ADULT MOBILITY: In the Baltic Sea, Norwegian fjords and the North Sea the sprats are genetically different (ICES, 2018) whereas in Kattegat and Skagerrak individuals appear to be a mixture of North Sea sprat and hybrids near the Swedish coast. By joining the survey from Skagerrak-Kattegat and the North Sea, the consistency between the assessment and the survey was improved (ICES, 2018) and provided a clear identification of the stock area (3.a and 4), excluding sprat in Norwegian fjords. However, uncertainties subsist about the connectivity of peripheral and/or geographically isolated sprat populations to the main stock in the southern North Sea, such as those in the Moray Firth Northeast Scotland, Firth of Forth East Scotland and the English Channel (ICES, 2018).

DISPERSAL OF EARLY LIFE STAGES: Sprat eggs drift and after about a week (~ 3 mm length) they hatch. They are thus widely spread by currents (Pethon, 2005).

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: Various studies on eggs and yolk

sac larvae (Kanstinger, 2007; Nissling, 2004; Petereit et al., 2008; Thompson et al., 1981) suggest that temperatures between 7 and 13 °C support higher survival of these stages. Sub-optimal temperatures range between 5 and 7 °C as well as 13-17 °C and 1-3 °C and 17-20 °C result in high mortality. Spawning temperatures are within these thermal boundaries. The duration of the endogenous feeding period is 135 ± 3 degree-days (°C d) at constant temperatures between 5 and 13 °C (Kanstinger, 2007; Nissling, 2004; Petereit et al., 2008; Thompson et al., 1981). The larva starts exogenous feeding with a standard length of ~ 5.5 mm.
COMPLEXITY IN REPRODUCTIVE STRATEGY: Sprat is an indeterminate batch spawner, as many other clupeiform species that spawns over a prolonged period between 6 and 15 °C (depending on spawning time at different latitudes) (Peck et al., 2012). Spawning season duration, batch fecundity and frequency are expected to vary both, within and between years in all regions (Alheit, 1988; Alshuth, 1988; Heidrich, 1922).

SPAWNING CYCLE: Even though some individuals may spawn at age 1, adults are generally mature at 2 years (Bailey, 1980). As a multiple batch spawner, sprat releases several egg batches throughout the spawning season (up to 10 in some areas) (George & Alheit, 1987). Sprat spawns in both coastal and offshore waters (Whitehead, 1985) and relative fecundity, peak spawning vary significantly between years and regions (Alheit et al., 1987). In northern European waters (North and Baltic Seas), peak spawning occurs at water temperatures between 8 and 15 °C, during spring and early summer (Petrova, 1960; Wahl & Alheit, 1988). In all regions, however, the onset and duration of spawning may vary due to temperature and feeding conditions. Main spawning grounds are located in the inner German Bight, off Jutland, along the English coast, and in areas west and north of Scotland (Munk, 1991).

SENSITIVITY TO TEMPERATURE: As mentioned above, successful spawning and early life stages (ELS) occur between 5 and 17 °C (Kanstinger, 2007; Nissling, 2004; Petereit et al., 2008; Thompson et al., 1981).

SENSITIVITY TO OCEAN ACIDIFICATION: There are limited data on the influence of ocean acidification (OA). However, there is no reason to doubt that OA will affect stock productivity if the "business-as-usual" scenario continues, with particular reference to increased ELS mortality. Indirect effects of OA should also be considered in projections, such as changes in food web dynamics.

POPULATION GROWTH RATE: Sprat has a short lifespan, rarely >5 years (Bailey, 1980) or a total length >16 cm (Whitehead, 1985), early reproduction, and low biomass. Therefore, sprat is considered an r-selected species (Mac Arthur & Wilson, 1967).

STOCK SIZE/STATUS: For short-lived species, like sprat, MSY $B_{escapement}$ is a biomass reference point, and the technical basis for this reference point in North Sea sprat is B_{pa}. The spawning stock biomass (SSB) used for comparison is the average of the ICES SSB estimates for 2009-2018, since the SSB of these short-lived species vary significantly from year to year. MSY $B_{escapement}$ = 125 000 tonnes; $SSB_{2009-2018}$ = 197 000 tonnes; $SSB_{2009-2018}$/ MSY $B_{escapement}$ = 197/125 = 1.6

OTHER STRESSORS: The most important stressors are likely fishing, as well as climate-driven temperature increases. Changes in temperature in the North Sea has increased the abundance of potential competitors, like anchovy and sardines (Fernandes et al., 2017), and potential predators like e.g. hake (Staby et al., 2018).

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 North Sea sprat (*Sprattus sprattus*) 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.

North Sea sprat (*Sprattus sprattus*) in ICES subarea 4 and division 3.a

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	4	1	0	0	**1.2**		
Prey Specificity	0	5	0	0	**2.0**		
Species Interaction	0	4	1	0	**2.2**		
Adult Mobility	0	4	1	0	**2.2**		
Dispersal of Early Life Stages	5	0	0	0	**1.0**		
ELH Survival and Settlement Requirements	0	4	1	0	**2.2**		
Complexity in Reproductive Strategy	4	1	0	0	**1.2**		
Spawning Cycle	2	3	0	0	**1.6**		
Sensitivity to Temperature	5	0	0	0	**1.0**		
Sensitivity to Ocean Acidification	5	0	0	0	**1.0**		
Population Growth Rate	4	1	0	0	**1.2**		
Stock Size/Status	5	0	0	0	**1.0**		
Other Stressors	0	5	0	0	**2.0**		
Grand mean					**1.52**		
Grand mean SD					**0.52**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	0	4	1	0	**2.2**		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
pH (Surface)	0	0	0	0		N/A	
Gross Primary Production	3	2	0	0	**1.4**		1
Gross Secondary Production	3	2	0	0	**1.4**		1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.60**		
Grand mean SD					**0.40**		
Accumulated Directional Effect					**–**		**3.6**

***Accumulated Directional Effect*: POSITIVE**	**3.6**

References

Alheit, J. (1988). Reproductive biology of sprat (*Sprattus sprattus*): Factors determining annual egg production. *ICES Journal of Marine Science*, *44*(2), 162–168.

Alheit, J., Wahl, E., & Cihangir, B. (1987). Distribution, abundance, development rates, production and mortality of sprat eggs. *ICES Council Meeting Papers*, *H: 45*.

Alshuth, S. (1988). Seasonal variations in length-frequency and birthdate distribution of juvenile sprat (*Sprattus sprattus*). *ICES Council Meeting Papers*, *H: 44*.

Araújo, F. G., Williams, W. P., & Bailey, R. G. (2000). Fish assemblages as indicators of water quality in the middle Thames estuary, England (1980–1989). *Estuaries*, *23*(3), 305–317.

Bailey, R. (1980). Problems in the management of short-lived pelagic fish as exemplified by North Sea sprat. *Rapports et Proces-Verbaux Des Reunions, Conseil International Pour L'Exploration de La Mer*, *177*, 477–488.

Bernreuther, M. (2007). *Investigations on the feeding ecology of Baltic Sea herring (*Clupea harengus *L.) and sprat (*Sprattus sprattus *L.)* [Doctoral dissertation]. Institute for Hydrobiology and Fisheries Science, University of Hamburg.

Blaxter, J., & Hunter, J. (1982). The biology of the clupeoid fishes. *Advances in Marine Biology*, *20*, 1–223.

Daan, N., Bromley, P., Hislop, J., & Nielsen, N. (1990). Ecology of North Sea fish. *Netherlands Journal of Sea Research*, *26*(2–4), 343–386.

De Silva, S. (1973). Food and feeding habits of the herring *Clupea harengus* and the sprat *C. sprattus* in inshore waters of the west coast of Scotland. *Marine Biology*, *20*(4), 282–290.

Ellis, T., & Nash, R. (1997). Predation by sprat and herring on pelagic fish eggs in a plaice spawning area in the Irish Sea. *Journal of Fish Biology*, *50*(6), 1195–1202.

Fernandes, J. A., Papathanasopoulou, E., Hattam, C., Queirós, A. M., Cheung, W. W., Yool, A., Artioli, Y., Pope, E. C., Flynn, K. J., Merino, G., Calosi, P., Beaumont, N., Austen, M., Widdicombe, S., & Barange, M. (2017). Estimating the ecological, economic and social impacts of ocean acidification and warming on UK fisheries. *Fish and Fisheries*, *18*(3), 389–411.

George, M., & Alheit, J. (1987). Ovarian maturation cycle of sprat, *Sprattus sprattus*. *ICES Council Meeting Papers*, *H: 47*.

Heidrich, H. (1922). Über die Fortpflanzung von *Clupea sprattus* in der Kieler Bucht. *Wissenschaftliche Meeresuntersuchungen Neue Folge*, *20*, 1–47.

ICES. (2018). *Benchmark Workshop on Sprat (WKSPRAT 2018)* (ICES Document CM ACOM: 35; p. 60). ICES.

Kanstinger, P. (2007). *Growth and condition of larval sprat (*Sprattus sprattus*): A combined laboratory and field investigation* [Doctoral dissertation]. University of Hamburg.

Mac Arthur, R., & Wilson, O. (1967). *The Theory of Island Biogeography*. Princeton University Press.

Maes, J., Tackx, M., & Soetaert, K. (2005). The predation impact of juvenile herring *Clupea harengus* and sprat *Sprattus sprattus* on estuarine zooplankton. *Hydrobiologia*, *540*(1), 225–235.

Munk, P. (1991). *Changes in mean size and distribution of juvenile North Sea sprat (*Sprattus sprattus *L.) in the period 1976-90*. *H: 41*, 6.

Muus, B., Nielsen, J., Dahlstrom, P., & Nystrom, B. (1999). *Sea Fish. Scandinavian Fishing Year Book–Hedehusene* (Narayana Press). Odder, Hedehusene.

Nissling, A. (2004). Effects of temperature on egg and larval survival of cod (*Gadus morhua*) and sprat (*Sprattus sprattus*) in the Baltic Sea—Implications for stock development. *Hydrobiologia*, *514*, 115–123.

Peck, M. A., Baumann, H., Bernreuther, M., Clemmesen, C., Herrmann, J.-P., Haslob, H., Huwer, B., Kanstinger, P., Köster, F. W., Petereit, C., Temming, A., & Voss, R. (2012). The ecophysiology of *Sprattus sprattus* in the Baltic and North Seas. *Progress in Oceanography*, *107*, 31–46.

Petereit, C., Haslob, H., Kraus, G., & Clemmesen, C. (2008). The influence of temperature on the development of Baltic Sea sprat (*Sprattus sprattus*) eggs and yolk sac larvae. *Marine Biology*, *154*(2), 295–306.

Pethon, P. (2005). *Aschehougs Store Fiskebok*. Aschehoug.

Petrova, E. (1960). On the fecundity and maturation of Baltic sprat. *Trudy Vsesojuznyj naucno issledovatelskij. Institut Morskogo Rybnogo Xozjajstva I Okeanografii VNIRO*, *42*, 99–108.

Raab, K., Nagelkerke, L., Boerée, C., Rijnsdorp, A., Temming, A., & Dickey-Collas, M. (2011). Anchovy *Engraulis encrasicolus* diet in the North and Baltic Seas. *Journal of Sea Research*, *65*(1), 131–140.

Russell, F. S. (1976). *The Eggs and Planktonic Stages of British Marine Fishes*. Academic Press.

Staby, A., Skjæraasen, J. E., Geffen, A. J., & Howell, D. (2018). Spatial and temporal dynamics of European hake (*Merluccius merluccius*) in the North Sea. *ICES Journal of Marine Science*, *75*(6), 2033–2044.

Thompson, B. M., Milligan, S., & Nichols, J. (1981). The development rates of sprat (*Sprattus sprattus* L.) eggs over a range of temperatures. *ICES Council Meeting Papers*, *H: 15*.

Valenzuela, G. S., & Vargas, C. A. (2002). Comparative larval growth rate of *Sprattus sprattus* in relation to physical and biological oceanographic features in the North Sea. *Archive of Fishery and Marine Research*, *49*(3), 213–230.

Voss, R., Dickmann, M., & Schmidt, J. O. (2009). Feeding ecology of sprat (*Sprattus sprattus* L.) and sardine (*Sardina pilchardus* W.) larvae in the German Bight, North Sea. *Oceanologia*, *51*(1), 117–138.

Wahl, E., & Alheit, J. (1988). Changes in the distribution and abundance of sprat eggs during spawning season. *ICES Council Meeting Papers*, *H: 45*.

Whitehead, P. (1985). *Clupeoid Fishes of the World. An Annotated and Illustrated Catalogue of Herrings, Sardines, Pilchards, Sprats, Shads, Anchovies and Wolf-Herrings. Part 1 Chirocentridae, Clupeidae and*

Pristigasteridae (Vol. 125). FAO Fisheries Synopsis.