NORWAY POUT IN THE BARENTS AND NORWEGIAN SEAS

Stock name: Norway pout
Latin name: *Trisopterus esmarkii*
Geographical area: Barents and Norwegian Seas (ICES subareas 1 and 2)
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Date: 26 March 2020

Stock Sensitivity Attributes

HABITAT SPECIFICITY: Norway pout (*Trisopterus esmarkii*, Gadidae) is widely distributed in the Northeast Atlantic, from the southwest Barents Sea, sometimes at Bear Island, south to the English Channel and the Bay of Biscay, around Iceland and Faeroe Islands (Svetovidov et al., 1986). The present assessment focuses on the Norway pout associated with ICES Subareas 1 (Barents Sea) and 2 (Norwegian Sea). Here, Norway pout is distributed from the Møre coast in the south and northwards above the continental shelf to the Barents Sea (Lahn-Johannessen, 1966). At the southernmost extension of the Møre coast, the spatial extent of Norway pout is continuous to the northern edge of the North Sea, implying that there is no clear distinction between the North Sea component and the component of the Norwegian and Barents Seas. In the Barents Sea Norway pout is confined to the Atlantic water masses (Mikkelsen, 2014; Wienerroither et al., 2013) with highest concentrations from Tromsøflaket and eastwards to Kildinbanken. Lower concentrations are stretching out along two branches: northwards along the West-Spitsbergen Current to the northern edge of Svalbard and in the Atlantic water masses northeastwards to Storbanken. Norway pout, like the other cold-temperate, shelf-based, gadoids cod, haddock, and saithe, is a generalist covering a wide geographical range of the Northeast Atlantic continental shelf. Hence, these species have all cold-temperate (boreal) habitats, in the range from the temperate boundary in the southern North Sea to the Arctic front in the Barents Sea and north of Svalbard, a distance of about 3,500 km. We will, however, in the following argue that two subpopulations exist: A North Sea stock in the south (see separate narrative), and a northerly component suggested to be defined as a Northeast Arctic stock of Norway pout. At the present stage, there is no information on whether the two populations can be genetically separated in two metapopulations. However, they are, indeed, physically separated by the circulation pattern during the early life history, from spawning during spring to settlement of the 0-group in early autumn.

PREY SPECIFICITY: Studies on prey selection are mainly confined to the North Sea. Here, the prey types consist of small organisms, mainly zooplankton (Albert, 1994; Raitt & Adams, 1965). Pelagic 0-group stays in the upper 50 m of the water column and feeds mainly on copepods and appendicularians (Robb & Hislop, 1980), whereas larger specimens (10-20 cm total length), that are found deeper in the water column, prefer mysids, natantids, copepods, euphausiids and amphipods in addition to small fishes, mainly gobies (Hislop et al., 2015). Feeding activity peaks during night (Albert, 1994; Raitt & Adams, 1965). Studies along the Norwegian shelf north of 62 °N show that Norway pout are mainly bottom based but ascend from the bottom to prey on the underside of swarms of krill, particularly *Thysanoessa inermis* (Kaartvedt et al., 1996). Norway pout is mainly found at the bottom, at least during day and ascends to variable degree during night-time for feeding (Torgersen et al., 1997). It seems that it maintains it bottom position to a larger degree throughout the 24-hour cycle in the northern part of the shelf, while diurnal vertical migrations seem to be more pronounced in the southern part of the shelf (Torgersen, 1996). On the other hand, there are also examples that Norway pout occurs in the upper layers even at daytime; it has been shown that the vertical migration was more closely linked to the actual optical properties (e.g. light penetration and fluorescence fluctuations) of water column rather than a fixed 24-hour cycle (Kaartvedt et al., 1996).

SPECIES INTERACTION: Comprehensive stomach sampling programs in the North Sea 1981-1991 (Daan, 1989; Hislop et al., 1997) have shown that other gadoids, i.e. cod, whiting and saithe, are major predators of the larger individuals of Norway pout close to the sea floor, whereas mackerel is an important predator on the pelagic 0-group fish. Hence, Norway pout is one of the important key species preying on zooplankton and being top-down controlled by larger predators, particularly the large gadoids, in the North Sea ecosystem. The close link between the four major cold-temperate (boreal) species (cod, haddock, saithe and Norway pout) is that the spawning areas of the four species in the North Sea (Sundby et al., 2017), as well as in the Møre-Lofoten region for the four Northeast Arctic stocks (Sundby et al., 2013) largely overlap. This is an additional indication of that Norway pout is a significant prey item for the larger gadoids in both regions.

ADULT MOBILITY: During warm periods, there are indications that the abundance is higher at the northeastern fringe, in the Barents Sea, while abundances are higher in the southernmost areas, i.e. Southern North Sea and English Channel during cooler conditions (Blacker, 1981). No information exists about possible metapopulations/subpopulations within this large area of distribution. However, the spawning areas in the North Sea (Sundby et al., 2017) are spatially separated from the spawning areas along the coast of Norway north of 62 °N (Sundby et al., 2013). Moreover, the transport of pelagic offspring from the two spawning areas are towards the south in the North Sea and towards the north at the coast of Norway north of 62 °N. Hence, during the eggs, larval and pelagic juvenile stages the offspring are transported in opposite directions from the two major spawning sites. This is indicative of that two separate subpopulations exist. Besides this, this pattern is parallel to the spawning areas of the other three major gadoid stocks: cod, haddock, saithe in the Barents and North Seas, respectively. Each of them has their main spawning areas from Møre to the Lofoten region (Sundby et al., 2013) and in the northern North Sea (Sundby et al., 2017), respectively, and cod, haddock and saithe are considered as separate stock in the two regions.

DISPERSAL OF EARLY LIFE STAGES: Norway pout north of 62 °N spawns mainly above the shelf in the Møre region and in Lofoten-Vesterålen (Sundby et al., 2013). Spawning occurs in March-April. The offspring is mainly transported with the Norwegian Coastal Current and subsequently partly by the Atlantic Current north-eastwards into the Barents Sea. Spawning areas as well as the spawning seasons are overlapping with those of the Northeast Arctic stocks of cod, haddock and saithe. During the recent 35 years of warming in the North Atlantic, the Northeast Arctic cod has expanded its habitat, including the location of the spawning areas (Sundby & Nakken, 2008), farther north and east into the Barents Sea and increased in abundance (Hollowed & Sundby, 2014; Kjesbu et al., 2014). The same development has occurred with spawning stock biomass (SSB) of the Northeast Arctic haddock (Landa et al., 2014). Also, the northern component of Norway pout has shown an increase in biomass from 1994, when the estimated number of fish in the Barents Sea was 0.2×10^9 individuals, until it peaked in 2011 with an estimated number of 4.3×10^9 individuals (Mikkelsen, 2014). A displacement towards east and north in the Barents Sea occurred during the same period (Mikkelsen, 2014). Particularly, the abundance has increased after 2004 in the southwestern areas of distribution, i.e. at Tromsøflaket and Nordkappbanken. It is to be expected that part of the adult and fishable stock is also found southwest of Tromsøflaket along the continental shelf of northern Norway (Kaartvedt et al., 1996; Lahn-Johannessen, 1966; Torgersen, 1996) implying that the above estimates confined to the Barents Sea are minimum estimates of the Northeast Arctic Norway pout stock. Quantitative observations in this region are, however, lacking. Even the minimum estimate for the Northeast Arctic Norway pout indicates that this component is larger than the North Sea component.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: No information exists on food requirements for early life stages of Norway pout north of 62 °N. Therefore, this must be based on the information on the North Sea stock: Pelagic 0-group feeds mainly on copepods and appendicularians (Robb & Hislop, 1980), while larger specimens (10-20 cm) prefer mysids, natantids, copepods, euphausiids and amphipods in addition to small fishes, mainly gobies (Hislop et al., 2015). The recruitment of Norway pout is very variable (ICES, 2017) and declining over the recent 25 years, possibly linked to the increasing temperature. Mortality of this short-lived species increases markedly with age. Maturation occurs after 1 or 2 years. There are indications of that the large and variable mortality is a combination of high predation pressure (Huse et al., 2008), high fishing pressure, and the possibility that a large and variable fraction of the adults die after spawning (Sparholt et al., 2002a, 2002b), hence similar to the variable stock structure of capelin. Recruitment variability is mainly controlled by predation pressure and sea surface temperature during spring (Kempf et al., 2009). However, it seems evident from timeseries on the North Sea stock abundance that the interannual variability is substantially larger than for the stock north of 62 °N. It could be due to that the latter stock is dominated by a continuous increase (Mikkelsen, 2014).

COMPLEXITY IN REPRODUCTIVE STRATEGY: As pointed out in the paragraph above on SPECIES INTERACTIONS, there are parallel features of the temporal development of the two cold-temperate (boreal) sets of gadoids species in the North Sea and north of 62 °N. Generally, in the North Sea stock abundances have declined during the recent warming since 1980s, while north of 62 °N the species have increased in abundances as well as in their habitat extents (Sundby et al., 2013, 2017). In both systems Norway pout is prey for larger gadoids. Under future climate change it is to be expected an onward increase in abundance of the gadoids with increased habitat extent.

SPAWNING CYCLE: Norway pout north of 62 °N is a spring spawner, similar to practically all high-latitude fish stocks, implying a spawning season limited to March and April (Sundby et al., 2013). However, at high-latitudes where fish species are tuned to reproduce as spring-spawners in order to synchronize with the plankton production (Sundby et al., 2017), it does not imply that they become more vulnerable to climate change.

SENSITIVITY TO TEMPERATURE: Norway pout as a species experience a broad temperature range as it is distributed from the English Channel to the Barents Sea (Mikkelsen, 2014; Svetovidov et al., 1986). The annual mean temperature at 100 m depth ranges from 10 °C in the southern North Sea to 1 °C in the northeastern Barents Sea. At the boundary of the two stocks in the northern North Sea/Møre coast the 100 m temperature is about 8 °C. The recruitment of North Sea Norway pout is sensitive to the combined effects of sea surface temperatures during the second quarter of the year (i.e. the egg and larval stages) and to a predation impact index (PI), and high temperatures negatively impacting recruitment in the North Sea, while in the Barents Sea high temperatures impacted the biomass positively (Kempf et al., 2009).

SENSITIVITY TO OCEAN ACIDIFICATION: Fin-fish species are most sensitive to ocean acidification (OA) during their earliest life stages, although experiments on North Sea species (such as cod and herring) have so far shown that they are relatively robust (Franke & Clemmesen, 2011; Pinnegar et al., 2016). It is reported that more work is needed before definitive conclusions can be made about the impact of OA on fin-fish in the North Sea.

POPULATION GROWTH RATE: The various descriptors of Norway pout for the North Sea population growth rates: maximum length (35 cm): low score; maximum age (5 years): low score; age-at-maturity (1-2 years): low score; von Bertalanffy K: low score. For the Barents Sea population these parameters are unknown, and we assume approximately similar values as in the North Sea (see Norway pout in the North Sea).

STOCK SIZE/STATUS: The current state of Barents Sea Norway pout is good after a strongly increased biomass since 1994 peaking in 2011 (Mikkelsen, 2014). A rapid decrease occurred thereafter, but the stock is still assumed to be above the long-term average.

OTHER STRESSORS: Recruitment has been continuously increasing since 1994, and a rapid increase occurred during the period 2005-2011. The stock showed a rapid decrease from 2011-2013 (Mikkelsen, 2014). No published data is available thereafter.

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 Norway pout (*Trisopterus esmarkii*) 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.

Norway pout (*Trisopterus esmarkii*) in ICES Subareas 1 and 2

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	5	0	0	0	**1.0**		
Prey Specificity	4	1	0	0	**1.2**		
Species Interaction	0	0	5	0	**3.0**		
Adult Mobility	0	5	0	0	**2.0**		
Dispersal of Early Life Stages	5	0	0	0	**1.0**		
ELH Survival and Settlement Requirements	1	3	1	0	**2.0**		
Complexity in Reproductive Strategy	0	5	0	0	**2.0**		
Spawning Cycle	0	0	5	0	**3.0**		
Sensitivity to Temperature	0	5	0	0	**2.0**		
Sensitivity to Ocean Acidification	0	0	5	0	**3.0**		
Population Growth Rate	5	0	0	0	**1.0**		
Stock Size/Status	0	5	0	0	**2.0**		
Other Stressors	0	5	0	0	**2.0**		
Grand mean					**1.94**		
Grand mean SD					**0.74**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	1	2	2	0	**2.2**	2	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	-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	2	2	1	0	**1.8**	1	1
Sea Ice Abundance	4	1	0	0	**1.2**	1	1
Grand mean					**1.50**		
Grand mean SD					**0.41**		
Accumulated Directional Effect					**–**		**3.8**

***Accumulated Directional Effect*: POSITIVE**	**3.8**

References

Albert, O. T. (1994). Biology and ecology of Norway pout (*Trisopterus esmarki* Nilsson, 1855) in the Norwegian Deep. *ICES Journal of Marine Science*, *51*(1), 45–61.

Blacker, R. (1981). Recent occurrences of blue whiting, *Micromesistius poutassou*, and Norway pout, *Trisopterus esmarkii*, in the English Channel and southern North Sea. *Journal of the Marine Biological Association of the United Kingdom*, *61*(2), 307–313.

Daan, N. (1989). *Data base report of the stomach sampling project 1981* (ICES Cooperative Research Report No. 164; ICES Cooperative Research Report, p. 144). ICES.

Franke, A., & Clemmesen, C. (2011). Effect of ocean acidification on early life stages of Atlantic herring (*Clupea* *harengus* L.). *Biogeosciences*, *8*(12), 3697–3707.

Hislop, J., Bergstad, O., Jakobsen, T., Sparholt, H., Blasdale, T., Wright, P., Kloppmann, M., Hillgruber, N., & Heessen, H. (2015). Norway pout – *Trisopterus esmarkii* Nilsson, 1855. In H. Heessen, N. Daan, & J. Ellis (Eds.), *Fish Atlas of the Celtic Sea, North Sea, and Baltic Sea* (pp. 209–212). Wageningen Academic Publishers and KNNV Publishing.

Hislop, J., Bromley, P., Daan, N., Gislason, H., Heessen, H., Robb, A., Skagen, D., Sparholt, H., & Temming, A. (1997). *Database report of the stomach sampling project, 1991* (ICES Cooperative Research Report No. 219; ICES Cooperative Research Report, p. 422). ICES.

Hollowed, A. B., & Sundby, S. (2014). Change is coming to the northern oceans. *Science*, *344*(6188), 1084–1085.

Huse, G., Salthaug, A., & Skogen, M. D. (2008). Indications of a negative impact of herring on recruitment of Norway pout. *ICES Journal of Marine Science*, *65*(6), 906–911.

ICES. (2017). *Report of the Benchmark Workshop on Norway Pout (*Trisopterus esmarkii*) in Subarea 4 and Division 3a (North Sea, Skagerrak, and Kattegat)* (ICES Document CM ACOM: 35; p. 69). ICES.

Kaartvedt, S., Melle, W., Knutsen, T., & Skjoldal, H. R. (1996). Vertical distribution of fish and krill beneath water of varying optical properties. *Marine Ecology Progress Series*, *136*, 51–58.

Kempf, A., Floeter, J., & Temming, A. (2009). Recruitment of North Sea cod (*Gadus morhua*) and Norway pout (*Trisopterus esmarkii*) between 1992 and 2006: The interplay between climate influence and predation. *Canadian Journal of Fisheries and Aquatic Sciences*, *66*(4), 633–648.

Kjesbu, O. S., Bogstad, B., Devine, J. A., Gjøsæter, H., Howell, D., Ingvaldsen, R. B., Nash, R. D. M., & Skjæraasen, J. E. (2014). Synergies between climate and management for Atlantic cod fisheries at high latitudes. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3478–3483. https://doi.org/10.1073/pnas.1316342111

Lahn-Johannessen, J. (1966). Some observations on Norway pout and blue whiting in ICES sub-areas I and II. *Contribution to ICES Symposium 17. The Ecology of Pelagic Fish Species in Arctic Waters*, 10.

Landa, C. S., Ottersen, G., Sundby, S., Dingsør, G. E., & Stiansen, J. E. (2014). Recruitment, distribution boundary and habitat temperature of an arcto-boreal gadoid in a climatically changing environment: A case study on Northeast Arctic haddock (*Melanogrammus aeglefinus*). *Fisheries Oceanography*, *23*(6), 506–520.

Mikkelsen, G. (2014). *Changes in Norway pout (*Trisopterus esmarkii*) abundance and distribution under warming conditions in the Barents Sea* [Master Thesis]. University of Bergen.

Pinnegar, J. K., Engelhard, G. H., Jones, M. C., Cheung, W. W., Peck, M. A., Rijnsdorp, A. D., & Brander, K. M. (2016). Socio-economic Impacts—Fisheries. In M. Quante & F. Colijn (Eds.), *North Sea Region Climate Change Assessment. Regional climate study* (pp. 375–395). Springer.

Raitt, D. F. S., & Adams, J. (1965). *The food and feeding of* Trisopterus esmarkii *(Nilsson) in the northern North Sea.* (No. 3; p. 28). Her Majesty's Stationery Office.

Robb, A., & Hislop, J. (1980). The food of five gadoid species during the pelagic O-group phase in the northern North Sea. *Journal of Fish Biology*, *16*(2), 199–217.

Sparholt, H., Larsen, L. I., & Nielsen, J. R. (2002a). Non-predation natural mortality of Norway pout (*Trisopterus esmarkii*) in the North Sea. *ICES Journal of Marine Science*, *59*(6), 1276–1284.

Sparholt, H., Larsen, L. I., & Nielsen, J. R. (2002b). Verification of multispecies interactions in the North Sea by trawl survey data on Norway pout (*Trisopterus esmarkii*). *ICES Journal of Marine Science*, *59*(6), 1270–1275.

Sundby, S., Fossum, P., Sandvik, A. D., Vikebø, F., Aglen, A., Buhl-Mortensen, L., Folkvord, A., Bakkeplass, K., Buhl-Mortensen, P., & Johannessen, M. (2013). *KunnskapsInnhenting Barentshavet–Lofoten–Vesterålen (KILO)* (Vol. 3). Havforskningsinstituttet.

Sundby, S., Kristiansen, T., Nash, R., Johannessen, T., Bakkeplass, K., Höffle, H., & Opstad, I. (2017). Dynamic mapping of North Sea spawning–Report of the KINO Project. *Fisken Og Havet*, *2*, 195.

Sundby, S., & Nakken, O. (2008). Spatial shifts in spawning habitats of Arcto-Norwegian cod related to multidecadal climate oscillations and climate change. *ICES Journal of Marine Science*, *65*(6), 953–962. https://doi.org/10.1093/icesjms/fsn085

Svetovidov, A., Whitehead, P., Bauchot, M.-L., Hureau, J., Nielsen, J., & Tortonese, E. (1986). Gadidae. In *Fishes of the North-Eastern Atlantic and the Mediterranean* (Vol. 2, pp. 680–710). Unesco.

Torgersen, T. (1996). *Akustiske studier av fisk og makroplankton over kontinentalsokkelen og det østlige Norskehavet, mars 1992; fordeling, atferd og metodiske problemer.* [Master Thesis]. Universitetet i Oslo.

Torgersen, T., Kaartvedt, S., Melle, W., & Knutsen, T. (1997). Large scale distribution of acoustical scattering layers at the Norwegian continental shelf and the Eastern Norwegian Sea. *Sarsia*, *82*(2), 87–96.

Wienerroither, R., Johannesen, E., Dolgov, A. V., Byrkjedal, I., Aglen, A., Bjelland, O., Drevetnyak, K., Eriksen, K.

B., Høines, Å. S., Langhelle, G., Langøy, H., Murashko, P., Prokhorova, T., Prozorkevich, D., Smirnov, O., & Wenneck, T. (2013). *Atlas of the Barents Sea Fishes Based on the Winter Survey*. IMR-PINRO.