NORWAY POUT IN THE NORTH SEA

Stock name: Norway pout
Latin name: *Trisopterus esmarkii*
Geographical area: Greater North Sea = Skagerrak and North Sea (ICES subareas 3a and 4)
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: Norway pout (*Trisopterus esmarkii*, Gadidae) is a small (~20 cm length, rarely as large as 25 cm), short-lived, boreal species (Hislop et al., 2015) and 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 (ICES, 2017; Mikkelsen, 2014; Raitt & Adams, 1965). The present assessment focuses on Norway pout associated with the ICES Subareas 3a (Skagerrak) and 4 (North Sea), termed "Greater North Sea". Here, Norway pout is distributed throughout most of the Greater North Sea, but the major concentrations are found in the Northern North Sea and in Skagerrak (Hislop et al., 2015). In addition, Norway pout is relatively abundant in the Irish Sea and west of Scotland/Ireland. In the Southern North Sea and in the English Channel, Norway pout is rare. However, catches of Norway pout were reported in the English Channel in 1979 where it was mixed with high concentrations of blue whiting (Blacker, 1981). Also, some Norway pout were caught in the Southern North Sea in 1977-79. This extraordinary occurrence in these southern areas was ascribed to the result of changes in the ecosystem since 1964 (Blacker, 1981). These changes coincide with what was called the "gadoid outburst" (Cushing, 1984) during the 1960s and 1970s when cod and other gadoids increased in stock size and was distributed across the entire North Sea. It has been later pointed out (Sundby et al., 2017) that the "gadoid outburst" coincided with the recent cool phase of the Atlantic Multidecadal Oscillation (AMO), and hence is part of changes in abundance and poleward displacements on multidecadal scales (Drinkwater et al., 2014; Sundby & Nakken, 2008).

PREY SPECIFICITY: Norway pout tends to stay relatively deep in the water column, i.e. 80-250 m depth. However, the prey types consist of small organisms, mainly zooplankton (Albert, 1994; Raitt & Adams, 1965). The pelagic 0-group stays in the upper 50 m of the water column and 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). Feeding activity peaks during night (Albert, 1994; Raitt & Adams, 1965).

SPECIES INTERACTION: Norway pout is an important forage fish in the North Sea ecosystem. Stomach sampling programs 1981-1991 (Daan, 1989; Hislop et al., 1997) have shown that other major gadoids, i.e. cod, whiting and saithe, are major predators of the larger individuals located near the sea floor, while 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. With the experience from the gadoid outburst (Cushing, 1984), it can be concluded that the gadoids of the North Sea are largely covarying in stock size in responses to the large-scale long-term climate fluctuations (Hislop, 1996). Therefore, it is expected that responses to future climate change would to a large degree be parallel for the gadoids (Sundby et al., 2017).

ADULT MOBILITY: Norway pout is widely distributed along the Northeast Atlantic shelf region from the Irish Sea and west of Ireland via the Faroes and Iceland to the southeastern part of the Barents Sea (Svetovidov et al., 1986). During warm periods, there are indications that the abundance is higher at the northeastern fringe, in the Barents Sea (Mikkelsen, 2014), while it to a larger extent occupies 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, some authors suppose that the Norway pout in the North Sea and

Skagerrak/Kattegat belong to one "stock unit" (Hislop et al., 2015), but it is unclear whether the distributions west of Scotland and in the Irish Sea belong to a different stock. 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 egg, 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 pattern is parallel to what is reported for 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 units in the two regions.

DISPERSAL OF EARLY LIFE STAGES: Norway pout spawns mainly above the shelf in northernmost parts of the North Sea (> 100 m) between Shetland and Norway (Sundby et al., 2017). Smaller spawning areas are found towards the central part of the North Sea south to about 56 °N near the southeastern coast of Scotland. The spawning season of Norway pout is between January to April (Munk & Nielsen, 2005). This time period is consistent with the eggs and larvae found in the northern North Sea (Nash et al., 2012). The pelagic offspring are transported from the principal spawning areas in the north-western North Sea to the south-east and toward the Skagerrak. These transport patterns are largely similar to the transport pattern of the other major gadoids, cod, haddock, and saithe. If future climate change will displace the spawning areas of Norway pout in the northernmost part of the North Sea polewards, the next available spawning habitats will be the shelf off Møre. If so, the transport of the offspring will swap towards northeast and the Norway pout habitat in the North Sea will most probably vanish.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: 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).

COMPLEXITY IN REPRODUCTIVE STRATEGY: The four gadoid species cod, haddock, saithe and Norway pout share common traits in the North Sea: 1) They all have their distributional centres of gravity in the northern North Sea (Hislop et al., 2015). Hence, they are the most boreal of the many gadoids here, 2) Presently, they have all the most important spawning areas at the northernmost shelf region between Shetland and Norway (Sundby et al., 2017), 3) offspring pelagic drift occurs in a south-southeastward direction farther into the North Sea and partly into Skagerrak, but also with a certain loss into the Norwegian Coastal Current that transports the offspring northwards along the Norwegian coast and out of the North Sea ecosystem (Sundby et al., 2017), and 4) They all have responded similar to the long-term changes in stock abundances, hereunder, the "gadoid outburst" (Cushing, 1984) during the 1960s and 1970s and thereafter they have all declined (Hislop, 1996), most probably due to the increasing temperature in the North Sea. There are, however, certain features where Norway pout deviate from the other three gadoids: the decline in the stock set in somewhat later than for the other three gadoids, and Norway pout is the only one that inhabits the deepest part of the North Sea, i.e. the deep Skagerrak and the Norwegian Trench. As an important forage fish for the larger gadoids, it could be inferred that the abundance is somewhat lagged to the other gadoids in response to well-known predator-prey interactions. However, as temperature continues to increase, they will all encounter a less beneficial thermal habitat and, therefore will most likely decline in abundance.

SPAWNING CYCLE: A number of authors state that the stock spawns from January through April in the northern North Sea (Albert, 1994; Nash et al., 2012; Raitt & Mason, 1968). However, no clear peak is identified during this period. However, Norway pout is clearly a spring-spawning species as for the other North Sea gadoids (Sundby et al., 2017). In addition, they all have presently their major spawning areas in the northern part of the North Sea. It has shown that most fish stocks in the northern North Sea converge as spring spawners, while in the southern North Sea spawning periods are extended throughout the year. Future climate change with poleward displacement of spawning areas would jeopardize offspring to be maintained within the North Sea ecosystem, since suitable alternative spawning areas would then be displaced towards the Møre coast.

SENSITIVITY TO TEMPERATURE: The North Sea is the southernmost thermal habitat for Norway pout in the Northeast Atlantic. During cool periods, as the most recent one during the 1960s and 1970s the stock was found at low concentrations as far south as in the southern North Sea and in the English Channel (Blacker, 1981). In the present warm phase of the AMO distribution has been displaced polewards, and the southernmost distribution seems to be in the central part of the North Sea (Hislop et al., 2015). The major spawning areas are presently concentrated in the northernmost part of the North Sea (Sundby et al., 2017). In principle, boreal fish stocks in the North Sea may be able to maintain their stock sizes under increasing temperatures given that they were initially not entirely inhabiting the North Sea ecosystem. As temperature increases, they would then have the option to be displaced polewards without losing habitat area. However, Norway pout is presently spawning at the northern fringe of the North Sea ecosystem, and an onward poleward displacement of spawning areas would be difficult without the stock being shifted into the neighbouring ecosystem of the Møre shelf off mid Norway. Modelling of transport of other gadoid offspring from the northernmost part of the North Sea (Sundby et al., 2017), clearly shows that spawning at the northernmost sites in the North Sea induces a higher particle transport into the Norwegian Coastal Current and a transport northwards. Based on this experience, it might be that parts of the gadoid fish stocks spawned east of Shetland already utilizes the Møre shelf and the shelf of Nordland as nursery and young-fish habitat. Therefore, it could be suspected that the North Sea as habitat for the most cold-temperate (boreal) gadoids, i.e. cod, haddock, saithe and Norway pout is already under severe stress, while some of the less cold-temperate gadoids like whiting, poor cod, four-bearded rockling, and particularly, the five-bearded rockling still will continue in suitable habitat in the North Sea.

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 about the impact of OA on fin-fish in the North Sea can be made.

POPULATION GROWTH RATE: The various descriptors of Norway pout 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 (Cohen et al., 1990; ICES, 2017).

STOCK SIZE/STATUS: The current status of Norway pout is relatively good, where the spawning stock biomass (SSB) is estimated to have been fluctuating above the precautionary reference point for biomass (B_{pa}) for most of the time-series (ICES, 2017, 2019).

OTHER STRESSORS: Recruitment is very variable and was very week in the years after 2000 (ICES, 2017, 2019). In recent years the fishing pressure has been low, and the recruitment relatively strong.

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 3.a and 4. 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 3.a and 4

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	0	2	3	0	**2.6**	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	4	1	0	0	**1.2**	1	1
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.52**		
Grand mean SD					**0.61**		
Accumulated Directional Effect					**–**		**-2.8**

***Accumulated Directional Effect*: NEGATIVE**	**-2.8**

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