NORTHERN SHRIMP IN THE BARENTS SEA

Stock name: Northern shrimp
Latin name: *Pandalus borealis*
Geographical area: Barents Sea (ICES subarea 1 and 2)
Expert: Fabian Zimmermann, Guldborg Søvik, Carsten Hvingel
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Stock Sensitivity Attributes

HABITAT SPECIFICITY: Although northern shrimp (*Pandalus borealis*, Pandalidae) can be found on rocky substrate, the species occurs mostly on soft substrate with a high organic content (Shumway et al., 1985; Zimmermann et al., 2019). It can therefore be concluded that northern shrimp is mostly dependent on muddy sea floor. Such habitats are very common in the Barents Sea and constitute no relevant restriction.

PREY SPECIFICITY: Northern shrimp are omnivores that feed on detritus, plankton and invertebrates (Shumway et al., 1985).

SPECIES INTERACTION: There is no evidence of significant interspecific competition. Northern shrimp utilizes a broad prey spectrum (Shumway et al., 1985), increasing competition capacities on food resources. Other shrimp species partially overlap in distribution with northern shrimp, but typically occur in much lower densities. This implies that intraspecific competition predominantly regulates population dynamics whereas interspecific competition is most likely not relevant. Northern shrimp is preyed upon by many demersal fish species, particularly young cod (Holt et al., 2019). A strong negative relationship between abundance indices of northern shrimp and cod have been shown for several regions, including the Barents Sea (Worm & Myers, 2003). However, cod in the Barents Sea feed on a variety of food items and the diet is dominated by fish (Holt et al., 2019). Presently, both the shrimp and Northeast Arctic cod stocks are at high levels (ICES, 2019a, 2019b).

ADULT MOBILITY: Northern shrimps are mobile and hatching migrations of egg-bearing females as well as seasonal spatial shifts in the stock distribution have been observed, underlining the ability to migrate between sites (Shumway et al., 1985). The mobility may be high in respect to their small sizes, but it is somewhat limited compared to widely distributed fish species that are not constrained to muddy benthic habitats.

DISPERSAL OF EARLY LIFE STAGES: Larval planktonic stages have a duration of 2-3 months depending on water temperature (Shumway et al., 1985). The pelagic larval duration allows larvae to drift far depending on hatching location and currents (Jorde et al., 2015; Pedersen et al., 2003). The dispersal potential of the species is thus high, suggesting a high ability to colonize new (suitable) habitats.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: During the pelagic drift (Shumway et al., 1985) Northern shrimp depends on food availability being sensitive to environmental changes, notably temperature (Arnberg et al., 2013). Although the mechanisms are not well understood, recruitment success is highly variable. This indicates that there is a high sensitivity of early life stages to environmental changes (Koeller et al., 2009).

COMPLEXITY IN REPRODUCTIVE STRATEGY: Northern shrimp in the Barents Sea exhibits several characteristics that indicate a moderately complex reproductive strategy (Shumway et al., 1985): 1. Northern shrimps are hermaphrodites, developing from immature juveniles to mature males to immature females to mature females. 2. Females moult before mating and spawning. 3. Skipped spawning can occur in northern areas. The dependence of these characteristics and, thus, the reproductive strategy on specific environmental conditions is considered low.

SPAWNING CYCLE: Northern shrimp eggs are carried by the females for several months after spawning until the eggs hatch. Spawning and mating occur once a year during a relatively short period, and local stocks are adapted to the time the eggs develop to match hatching with the spring bloom (Koeller et al., 2009). Climate change induced shifts of the spring bloom may result in an increased risk of a mismatch between hatching time and the spring bloom. Specifically, increased climate variability may be problematic. It is unknown if or how fast the species could adapt the timing of spawning, incubation and hatching to changing environmental conditions.

SENSITIVITY TO TEMPERATURE: Northern shrimp is found within a large temperature range from below 0 to 10-12°C, occurring across 3 climate provinces (Bergström, 2000; Shumway et al., 1985). The species may be found at depths between 50 and 500 m. This suggests that the species has a high temperature tolerance and can adapt to increasing temperatures, particularly at its northern range limit in the Barents Sea. The temperature sensitivity of the Barents Sea stock is, however, less clear (Jorde et al., 2015). The stock exhibits a preference for a relatively narrow temperature range (0-4°C) and recent eastward shifts in its distribution have been attributed to changes in bottom temperatures (NAFO/ICES, 2019). It is unknown whether the stock could adapt to substantial changes in temperature and how this would affect its productivity. The sensitivity of the species is therefore considered low, whereas the sensitivity of the Barents Sea shrimp stock may possibly be high.

SENSITIVITY TO OCEAN ACIDIFICATION: As a crustacean, northern shrimp may be directly affected by ocean acidification (OA), specifically during early life stages and moulting. Experimental evidence suggests a slower development of early life stages under OA conditions (Arnberg et al., 2013; Bechmann et al., 2011). It is unknown whether adult shrimps will be affected by the levels of OA.

POPULATION GROWTH RATE: Northern shrimp is a relatively short-lived species with high productivity (Shumway et al., 1985) that falls into the low vulnerability bin. The Barents Sea stock is, however, slow growing compared to more southerly distributed populations. Although age determination is not possible, maximum age estimated to be 10 years in the Barents Sea. Natural mortality was estimated 0.75/year for the Barents Sea stock (Berenboim et al., 1991), but this estimate is highly uncertain. However, the life history cannot easily be compared to the standard categories used for fish (e.g. northern shrimp are hermaphrodites that subsequently undergo maturation for each sex). The shorter life cycle of more southern populations suggests that the Barents Sea stock might respond similarly to increasing temperatures, but the potential to adapt to environmental changes in the short term remains unclear.

STOCK SIZE/STATUS: Stock biomass is currently estimated to be well above biomass maximum sustainable yield and the risk of falling below biomass reference points is very low (ICES, 2019b). Fishing pressure has been low for many years, but may increase in the future due to a raised interest in this fishery (NAFO/ICES, 2019).

OTHER STRESSORS: No specific stressor is known for the offshore Barents Sea shrimp stock, which is dominating the total stock biomass. Fishing pressure is currently low (ICES, 2019b) and can be currently assumed a negligible stressor. The coastal part of the stock is, however, subject to multiple stressors that may have adverse effects on coastal shrimp populations. The stressors are mostly caused by human alterations of coastal habitats that result in habitat degradation (organic enrichment from fish farms, dumping of mining waste), changes in fjord hydrography due to hydropower plants changing river runoffs (Myksvoll et al., 2014), and direct adverse impacts, e.g. chemical delousing agents used in salmon farms (Grefsrud et al., 2019). In addition, an increase in hypoxic areas has been observed, potentially caused by aquaculture and/or changes in water mixing. Impact of stressors on the entire stock is low but may have substantial, negative effects locally.

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 shrimp (*Pandalus borealis*) stock 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 shrimp (*Pandalus borealis*) in ICES subareas 1 and 2

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	0	1	4	0	**2.8**		
Prey Specificity	4	1	0	0	**1.2**		
Species Interaction	2	3	0	0	**1.6**		
Adult Mobility	0	1	4	0	**2.8**		
Dispersal of Early Life Stages	5	0	0	0	**1.0**		
ELH Survival and Settlement Requirements	0	0	5	0	**3.0**		
Complexity in Reproductive Strategy	0	4	1	0	**2.2**		
Spawning Cycle	0	0	0	5	**4.0**		
Sensitivity to Temperature	2	0	0	3	**2.8**		
Sensitivity to Ocean Acidification	0	0	1	4	**3.8**		
Population Growth Rate	4	1	0	0	**1.2**		
Stock Size/Status	5	0	0	0	**1.0**		
Other Stressors	3	0	0	2	**2.2**		
Grand mean					**2.28**		
Grand mean SD					**1.03**		

CLIMATE EXPOSURE	L	M	H	VH	$Mean_w$	Usage	*Directional Effect*
Surface Temperature	0	0	0	0		N/A	
Temperature 100 m	0	0	0	0		N/A	
Temperature 500 m	0	0	0	0		N/A	
Bottom Temperature	4	1	0	0	**1.2**	1	1
O_2 (Surface)	0	0	0	0		N/A	
pH (Surface)	3	2	0	0	**1.4**	1	-1
Gross Primary Production	1	4	0	0	**1.8**	1	1
Gross Secondary Production	0	0	0	0		N/A	
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.47**		
Grand mean SD					**0.31**		
Accumulated Directional Effect					**–**		**1.6**

***Accumulated Directional Effect*: POSITIVE**	**1.6**

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