NORWAY LOBSTER IN THE NORWEGIAN DEEP

Stock name: Norway lobster in the Norwegian Deep
Latin name: *Nephrops norvegicus*
Geographical area: Northern North Sea, Norwegian Deep (ICES division 4.a East, Functional Unit 32)
Experts: Guldborg Søvik, Fabian Zimmermann
Date: 13 December 2019

Stock Sensitivity Attributes

HABITAT SPECIFICITY: Norway lobster (*Nephrops norvegicus*, Nephropidae) is found in the Mediterranean and the Northeast Atlantic, from Morocco and the Canary Islands to Troms, northern Norway, and around Iceland and the British Isles (FAO, 2020; Johnson et al., 2013). Throughout its distribution, *Nephrops* is limited to muddy habitat and requires sediment with silt and clay to excavate its burrows (Johnson et al., 2013). Therefore, the distribution of *Nephrops* is largely defined by the distribution of suitable sediment. A sediment map of the Norwegian Deep (www.mareano.no) shows that most of the area consists of soft sediments suitable for *Nephrops*. The species has been caught on most bottom trawl stations of an annual shrimp survey covering the Norwegian Deep and Skagerrak (ICES, 2019; Søvik et al., 2019). Along the Norwegian coast the distribution of *Nephrops* is determined by the patchy distribution of muddy sediment. The *Nephrops*' distribution *per se* has not been mapped, but northern shrimp (*Pandalus borealis*) grounds have been mapped by the Norwegian Fisheries Directorate (www.kart.fiskeridir.no). As the two species generally overlap, the distribution of *Nephrops* along the coast can be inferred from the distribution of northern shrimp.

PREY SPECIFICITY: Studies show that *Nephrops* is a varied feeder (generalist predator and scavenger) regardless of sex or size, feeding indiscriminately on the available organisms occurring on or just within the sea bottom sediment (Farmer, 1975). Stomach analyses have shown that *Nephrops* feeds on crustaceans, bivalves, small gastropods, annelids, echinoderms, Foraminifera and fish. There seems to be little seasonal variation in the diet. Berried females may suspend feeding for longer periods of time.

SPECIES INTERACTION: Intraspecific competition for food and space is demonstrated by negative relationships between size and density (Johnson et al., 2013). As knowledge on *Nephrops* has largely been shaped by fisheries-related research, interspecific interactions with species that are not targeted by fisheries are less understood. *Nephrops* may compete for food with other crustaceans like squat lobsters and crabs (Johnson et al., 2013). Competition for burrow space may also occur. *Nephrops* seem to have few predators (Johnson et al., 2013). Cod is the most important fish predator, but *Nephrops* may also be targeted by haddock, anglerfish, some elasmobranchs, and cephalopods.

ADULT MOBILITY: Tagging experiments have shown that adult *Nephrops* only undertake small-scale movements (Farmer, 1975).

DISPERSAL OF EARLY LIFE STAGES: The pelagic larvae drift with ocean currents for up to 50 days depending on temperature before settling on the bottom (Johnson et al., 2013). *Nephrops* populations in larger areas seem to exhibit a metapopulation structure with exchange of pelagic larvae between areas (O'Sullivan et al., 2015). Modelling studies have shown that larvae along the Iberian Peninsula may drift up to 100-300 km (Marta-Almeida et al., 2008), whereas larvae around Ireland may drift 200-650 km (O'Sullivan et al., 2015). No information is available on the extent of larval mixing between the *Nephrops* stock in the Norwegian Deep and the neighbouring stocks in Skagerrak and the Fladen Ground.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: The settling of *Nephrops* postlarvae depends on reaching suitable muddy habitat for building burrows and thus for surviving. Juvenile specimens are rarely found outside burrows of adults (Tuck et al., 1994); they seem to excavate their burrows within the burrows of adults. Thus, successful settlement of larvae in an area may depend on already existing burrows, i.e. an already established population (Johnson et al., 2013). This may limit the spread of the species to potential new suitable habitats. Recruitment is difficult to estimate for *Nephrops.* Discard estimates are often used as a proxy. Recruitment (as interpreted from discards) seems to vary over time for the Norwegian Deep stock (ICES, 2019), indicating some sensitivity to environmental conditions.

COMPLEXITY IN REPRODUCTIVE STRATEGY: *Nephrops* has separate sexes. Copulation seems to occur only between males and newly moulted, still soft-bodied females (Farmer, 1974, 1975). During copulation, the male transfers a spermatophore to the female. The species exhibits a moderately complex reproductive strategy, but the dependency on specific environmental conditions is relatively low.

SPAWNING CYCLE: *Nephrops* spawns once a year (Farmer, 1974, 1975; Powell & Eriksson, 2013). In more northern waters, egg production may be biannual. Egg-laying takes place over a period of a couple of months (August-September). Females carry the roe until hatching takes place in the following year. Hatching of the eggs of one female occurs at night-time over several successive days (5-20 days), while egg hatching within a local population takes place over a couple of months (April-June). The reproductive cycle, from egg laying to hatching, varies with temperature, and therefore between local populations.

SENSITIVITY TO TEMPERATURE: Throughout its distribution, *Nephrops* lives at depths between 20 and 800 m and in waters with temperatures between 6 and 17 °C (Johnson et al., 2013). In the Norwegian Deep, the species is found at depths between 100 and 350 m (Søvik et al., 2019). This suggests that *Nephrops* might tolerate increased sea temperatures in the northern part of its distribution range, like in the Norwegian Deep, but that it may be sensitive to increased temperatures in the southern part of its range. It is, however, unknown if local populations have more restricted temperature preferences. Bottom temperature in the Norwegian Deep in winter lies between 7 and 8 °C (Albretsen et al., 2012; Sætre et al., 2003). The 1st quarter mean bottom temperature in the Norwegian Deep varied between 6.6 and 8.2 °C in the period 2006-2019 (Søvik et al., 2019).

SENSITIVITY TO OCEAN ACIDIFICATION: One experimental study showed that *Nephrops* embryos were insensitive to low pH (Styf et al., 2013), while another experimental study showed brood specific sensitivity of larvae to ocean acidification (OA) with differences in mortality between broods (Wood et al., 2015). Reduced pH was shown to increase the energetic demand on the larvae, which could potentially have a negative effect later in development. A third study showed that negative effects of experimental OA treatment on the immune response and tissue homeostasis in adult *Nephrops* were more pronounced at higher temperatures (Hernroth et al., 2012). Crustaceans like *Nephrops* may therefore become more susceptible to diseases in a warmer and more acid ocean.

POPULATION GROWTH RATE: Biological data are lacking for the Norwegian Deep stock but exist for the neighbouring Skagerrak and Kattegat stock (ICES, 2019). For this stock, natural mortality (M) is assumed to be 0.3 for males of all ages, whereas M for immature and mature females is assumed to be 0.3 and 0.2, respectively. The growth parameters are as follows: males: $L_{infinity}$ = 73 mm carapace length (CL), K = 0.138, immature females: $L_{infinity}$ = 73 mm CL, K = 0.138, and mature females: $L_{infinity}$ = 65 mm CL, K = 0.10. Maximum total length is <55 cm. It is not possible to age *Nephrops* so maximum age is unknown. A tagged female in Skagerrak was recaptured after almost 13 years (M. Ulmestrand, personal communication), indicating that individuals can live for a long time. Whereas the growth parameters suggest that the stock should be categorized in the “high” population growth rate bin, the stock falls into the “low” to “moderate” population growth rate bins in terms of longevity.

STOCK SIZE/STATUS: Stock status and fishing pressure on the Norwegian Deep stock are unknown

(ICES, 2018). However, fishing pressure in offshore areas has been low for several years, and both the Danish and the Norwegian trawl fisheries are now mainly located in the southern part of the area (ICES, 2019). Trap fisheries, both commercial and recreational, are increasing in coastal areas of FU 32 (western Norway) (Søvik et al., 2016). Stock status and fishing pressure are also here unknown, but fishing pressure may be high.

OTHER STRESSORS: *Nephrops* is generally restricted to waters with relatively high salinity and oxygen concentration (Johnson et al., 2013). The species is susceptible to reduced oxygen levels. Severe depletion in oxygen content in the water can force the animals out of their burrows, thus temporarily increasing the trawl catchability during such environmental conditions (ICES, 2019). Hypoxic events are increasingly occurring in a warming ocean, but effects on *Nephrops* stocks are unknown. Salinity stress experiments have demonstrated increased energy usage of early life stages (Wood et al., 2015). Climate change with increased precipitation can cause reduced salinity in coastal areas and may alter the species' distribution in the future. Currently no impacts of specific stressors on *Nephrops* in the Norwegian Deep are known.

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 lobster (*Nephrops norvegicus*) in ICES division 4.a East, FU 32. 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 lobster (*Nephrops norvegicus*) in ICES division 4.a East, FU 32

SENSITIVITY ATTRIBUTES	L	M	H	VH	$Mean_w$	Usage	Remark
Habitat Specificity	0	1	3	1	**3.0**		
Prey Specificity	5	0	0	0	**1.0**		
Species Interaction	4	1	0	0	**1.2**		
Adult Mobility	0	1	3	1	**3.0**		
Dispersal of Early Life Stages	4	1	0	0	**1.2**		
ELH Survival and Settlement Requirements	0	0	4	1	**3.2**		
Complexity in Reproductive Strategy	0	5	0	0	**2.0**		
Spawning Cycle	0	0	4	1	**3.2**		
Sensitivity to Temperature	2	3	0	0	**1.6**		
Sensitivity to Ocean Acidification	0	2	3	0	**2.6**		
Population Growth Rate	1	3	1	0	**2.0**		
Stock Size/Status	3	0	2	0	**1.8**		
Other Stressors	4	1	0	0	**1.2**		
Grand mean					**2.08**		
Grand mean SD					**0.83**		

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
O_2 (Surface)	0	0	0	0		N/A	
pH (Surface)	3	2	0	0	**1.4**		-1
Gross Primary Production	4	1	0	0	**1.2**		0
Gross Secondary Production	0	0	0	0		N/A	
Sea Ice Abundance	0	0	0	0		N/A	
Grand mean					**1.27**		
Grand mean SD					**0.12**		
Accumulated Directional Effect					**–**		**-0.2**

***Accumulated Directional Effect*: NEUTRAL**	**-0.2**

References

Albretsen, J., Aure, J., Sætre, R., & Danielssen, D. S. (2012). Climatic variability in the Skagerrak and coastal waters of Norway. *ICES Journal of Marine Science*, *69*(5), 758–763.

FAO. (2020). *Species Fact Sheet.* Nephrops norvegicus *(Linnaeus, 1758).*

Farmer, A. (1974). Reproduction in *Nephrops norvegicus* (Decapoda: Nephropidae). *Journal of Zoology*, *174*(2), 161–183.

Farmer, A. (1975). *Synopsis of biological data on the Norway lobster* Nephrops norvegicus *(Linnaeus, 1758).* (No. 112; FAO Fisheries Synopsis, p. 108). FAO.

Hernroth, B., Sköld, H. N., Wiklander, K., Jutfelt, F., & Baden, S. (2012). Simulated climate change causes immune suppression and protein damage in the crustacean *Nephrops norvegicus*. *Fish & Shellfish Immunology*, *33*(5), 1095–1101.

ICES. (2018). *Norway lobster (*Nephrops norvegicus*) in Division 4.a, Functional Unit 32 (northern North Sea, Norway Deep)* (nep. fu.32.). ICES Advice on fishing opportunities, catch, and effort.

ICES. (2019). *Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) 2019* (ICES Scientific Reports 1: 7; p. 1271).

Johnson, M. P., Lordan, C., & Power, A. M. (2013). Habitat and ecology of *Nephrops norvegicus*. *Advances in Marine Biology*, *64*, 27–63.

Marta-Almeida, M., Dubert, J., Peliz, A., dos Santos, A., & Queiroga, H. (2008). A modelling study of Norway lobster (*Nephrops norvegicus*) larval dispersal in southern Portugal: Predictions of larval wastage and self-recruitment in the Algarve stock. *Canadian Journal of Fisheries and Aquatic Sciences*, *65*(10), 2253–2268.

O'Sullivan, D., Lordan, C., Doyle, J., Berry, A., & Lyons, K. (2015). Metapopulation connectivity via larval transport of the Norway lobster *Nephrops norvegicus* in waters around Ireland: A modelled approach. *Marine Ecology Progress Series*, *534*, 95–106.

Powell, A., & Eriksson, S. P. (2013). Reproduction: Life cycle, larvae and larviculture. *Advances in Marine Biology*, *64*, 201–245.

Sætre, R., Aure, J., & Danielssen, D. (2003). *Long-term hydrographic variability patterns off the Norwegian coast and in the Skagerrak*. *219*, 150–159.

Søvik, G., Furevik, D., Jørgensen, T., Bakke, S., Larssen, W., Thangstad, T., & Woll, A. (2016). The Norwegian *Nephrops* fishery – history, exploitation and management. In B. Thu & A. Gundersen (Eds.), *Sustainable Bio-Resources. Management, Product Development and Raw Material Quality* (pp. 95–118). Orkana Akademisk.

Søvik, G., Thangstad, T., & Vedholm, J. (2019). *Reketokt i Norskerenna og Skagerrak januar 2019* (Toktrapport No. 4–2019; p. 67). Havsforskningsinstituttet, IMR.

Styf, H. K., Sköld, H., & Eriksson, S. P. (2013). Embryonic response to long-term exposure of the marine crustacean *Nephrops norvegicus* to ocean acidification and elevated temperature. *Ecology and Evolution*, *3*(15), 5055–5065.

Tuck, I., Atkinson, R., & Chapman, C. (1994). The structure and seasonal variability in the spatial distribution of *Nephrops norvegicus* burrows. *Ophelia*, *40*(1), 13–25.

Wood, H., Eriksson, S., Nordborg, M., & Styf, H. (2015). The effect of environmental stressors on the early development of the Norway lobster *Nephrops norvegicus* (L.). *Journal of Experimental Marine Biology and Ecology*, *473*, 35–42.