

Stock name: Norway lobster in Skagerrak and Kattegat

Latin name: *Nephrops norvegicus*

Geographical area: Skagerrak and Kattegat (ICES division 3.a, Functional Units 3 and 4)

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Date: 17 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 habitats 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 Skagerrak (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, 2019b; Søvik et al., 2019). In the eastern part of Kattegat and Skagerrak (in Danish and Swedish waters), high concentrations of *Nephrops* are found on large, coherent mud flats (ICES, 2019b). Along the Norwegian Skagerrak coast, the distribution of *Nephrops* is more irregular due to the patchy distribution of muddy sediment sea floors. 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* preys 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). Interactions may also take place over burrow space. *Nephrops* seem to have few predators (Johnson et al., 2013). Cod is the most important fish predator, but the species 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), while 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 Skagerrak/Kattegat and the neighbouring stock in the Norwegian Deep.

EARLY LIFE HISTORY SURVIVAL AND SETTLEMENT REQUIREMENTS: The settling of *Nephrops* post-larvae 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. Recent recruitment (as interpreted from discards) has varied in the Skagerrak/Kattegat stock (ICES, 2019b), 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, and the dependency of the characteristics of the strategy on specific environmental conditions is 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 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 Skagerrak/Kattegat, the species lives at depths between 25 and 300 m (Søvik et al., 2019) (M. Ulmestrand, personal communication). This suggests that *Nephrops* might tolerate increased temperatures in the northern part of its distribution range, like in the Skagerrak/Kattegat region, 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 Skagerrak in winter lies between 7 and 8 °C (Albretsen et al., 2012; Sætre et al., 2003). The 1st quarter mean bottom temperature in Skagerrak varied between 5.4 and 7.8 °C in the period 2006-2019 (Søvik et al., 2019).

SENSITIVITY TO OCEAN ACIDIFICATION: Experimental studies showed that *Nephrops* embryos were insensitive to low pH (Styf et al., 2013) compared to 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 acidic ocean.

POPULATION GROWTH RATE: For the Skagerrak and Kattegat *Nephrops* stock, natural mortality (M) is assumed to be 0.3 for males of all ages, while M for respectively immature and mature females is assumed to be 0.3 and 0.2 (ICES, 2019b). The growth parameters are as follows: Males: $L_{\infty} = 73$ mm carapace length (CL), $K = 0.138$, immature females: $L_{\infty} = 73$ mm CL, $K = 0.138$, and mature females: $L_{\infty} = 65$ mm CL, $K = 0.10$. Maximum total length is <55 cm. It is not possible to age *Nephrops*, hence maximum age is unknown. A tagged female in Skagerrak was found 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: No reference points for stock size have been defined (ICES, 2019a). The size of the Skagerrak and Kattegat *Nephrops* stock is, however, considered stable. An underwater TV survey and commercial catch rates suggest a stable or increasing stock (ICES, 2019a, 2019b). The estimated harvest rate for the stock is currently below fishing mortality (F) maximum sustainable yield (MSY) (ICES, 2019a). Along the Norwegian Skagerrak coast, stock status and fishing pressure are unknown, but fishing pressure may be high (Søvik et al., 2016).

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, 2019b). 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.

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 3.a, FU 3 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 lobster (*Nephrops norvegicus*) in ICES division 3.a, FU 3 and 4

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	4	1	0	0	1.2		
Other Stressors	4	1	0	0	1.2		
Grand mean					2.03		
Grand mean SD					0.86		

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: NEGATIVE

-0.2

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