Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 4.a, Functional Unit 32 (northern North Sea, Norway Deep)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster (*Nephrops norvegicus*) in Division 4.a, Functional Unit 32 (northern North Sea, Norway Deep)
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A. General

A.1. Stock definition

Throughout its distribution, Norway lobster (*Nephrops norvegicus)* is limited to muddy habitat and requires sediment with a silt and clay content of between 10 – 100% to excavate its burrows. Therfore, the distribution of *Nephrops* is largely defined by the distribution of suitable sediments. Adult *Nephrops* only undertake small-scale movements, but larval drift may occur between separate mud patches in some areas. No information is available on the extent of larval mixing between the *Nephrops* stock in FU 32 and the neighbouring stocks in Skagerrak (FU 3) and Fladen Ground (FU 7).

The Norwegian Deep is located in the eastern part of ICES Division IVa. *Nephrops* has been caught on most trawl stations of the Norwegian annual shrimp survey covering the area. This indicates that the species is widely distributed in FU 32, but the exact distribution is not known. Sediment maps of the Norwegian Deep indicate that most of FU 32 consists of sediments suitable for *Nephrops* (Figure A1-1).

A Scandinavian Interreg project, ØBJ-FISK (2012-2014), investigated the genetic stock structure of *Nephrops* in the Norwegian Deep/Skagerrak/Kattegat area. Results showed no significant genetic differences between *Nephrops* in FU 32 and FUs 3 and 4 (Skagerrak and Kattegat) (Frandsen et al. 2015, Westgaard et al. in prep.). However, due to the different fisheries and fishing pressure, as well as differences in monitoring and assessment in FU 32 vs. FUs 3 and 4, the 2016 benchmark (ICES 2016) recommended to continue to keep these areas as separate management units.

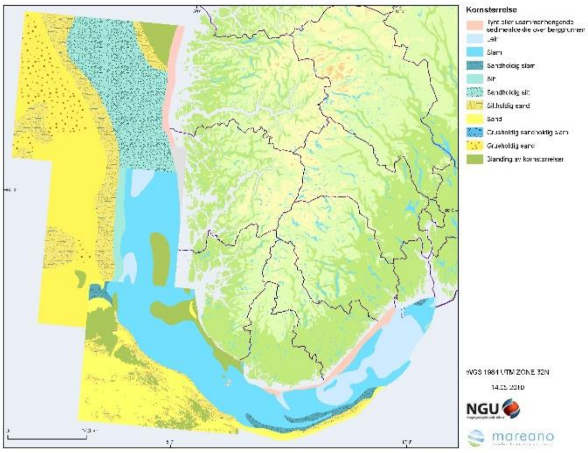

Figure A1-1. Sediment map of the Norwegian Deep and Skagerrak. Map from

www.mareano.no.

A.2. Fishery

Traditionally, Danish and Norwegian fisheries have almost exclusively exploited this stock, while exploitation by UK vessels has been insignificant. During the years 2000-2012, Sweden landed small amounts.

Danish fishery

The largest part of the landings in FU 32 were taken by Denmark until 2015. From 1995 to 2007 the Danish share of the landings was between 80 and 90%. With the steady decrease of the Danish landings since 2006 the Danish share has decreased accordingly. In 2017, Denmark landed only 36% of the total landings. The decline is due to several factors: increasing fuel costs, fewer vessels rendering it more difficult to exchange information on the best *Nephrops* grounds, and, following the change in mesh size legislation in 2004 (see below), Danish *Nephrops* landings from FU 32 are now bycatch from mixed fisheries.

Nephrops are fished all year round by the Danish fleet. The Danish *Nephrops* trawl fishery was earlier distributed along the western and southern slope of the Norwegian Deep. Since 2010, the fishery has gradually contracted into the southern part of FU 32. Due to changes in the management regime (mesh size regulations regarding target species) in the Norwegian Exclusive Economic Zone (EEZ) of the North Sea in 2004, there was a switch to increasing Danish effort targeting *Nephrops* in the mixed fisheries in the Norwegian Deep. However, a distinction between fishing effort directed at *Nephrops*, roundfish or anglerfish (*Lophius piscatorius*) is not always clear. The mesh size in the trawls catching *Nephrops* is ≥ 120 mm. The use of twin trawls has been widespread for many years.

Norwegian fishery

Nephrops are fished all year round by the Norwegian fleet. The *Nephrops* fishery north of 60 °N is now a trap fishery, but with varying amounts of landings from *Nephrops* trawls until 2014 (Søvik et al. 2016). South of 60 °N, *Nephrops* is fished by traps, and taken as bycatch in shrimp and large mesh demersal trawls. Norwegian landings decreased by 56% from 2008 to 2014, due to a decrease in landings from trawls. Trawl landings have been low since 2015, while landings from traps have increased, resulting in increased total landings, out of which trawl landings only constitute around 10%.

The poor shrimp fishery in the Norwegian Deep in recent years explains the low *Nephrops* landings from shrimp trawls. Changes taking place over several years, like the sorting grid in shrimp trawls compulsory from January 1, 2015 resulting in less *Nephrops* being caught, a discontinuation of the Norwegian directed *Nephrops* fishery due to the changed mesh size legislation in 2004 (see below), no trawling inside 4 nautical miles (see below), and bycatch restrictions, explain the shift from a trawl to a trap based fishery in FU 32 (Søvik et al. 2016).

The fleet north of 60 °N consists mainly of small vessels < 11 m. South of 60 °N, the fleet structure has changed from 2007 to present, with an increase in small vessels and a decrease in larger ones, resulting in the fleet in 2017 being dominated by vessels < 11 m. The change can be explained by a growing trap fishery, which is carried out mainly by small vessels (Søvik et al. 2016). Landings per ICES statistical rectangle (available from 2009) and electronic logbooks (available from 2011 for vessels ≥ 15 m) provide information on the spatial distribution of the fishery. In 2009-2010, the fishery was located more offshore compared with 2011 and 2012, which is in accordance with a sharp decrease in trawl landings from 2010 to 2011 of more than 60%. Haul positions from electronic logbooks show that the large vessels in 2011 and 2012 operated along the whole western and southern slope of the Norwegian Deep, while the trawl fishery in later years have taken part mostly in the southernmost part of FU 32 and along the coast. Since 2015, trap landings per ICES statistical rectangle have increased to > 10 tons along the coast from Stavanger to Bergen, indicating a high fishing pressure in this area. Additionally, the recreational trap fishery for *Nephrops* along the Norwegian coast has increased in recent years.

Regulations

The EU fisheries are managed through a TAC, determined at annual EU-Norway negotiations. The TAC has never constrained the EU fisheries. In 2005, 98% of the quota was taken, while only 5% was fished in 2017. There are no Norwegian quotas.

The management regime (mesh size regulations regarding target species) in the Norwegian EEZ of the North Sea was changed in 2004 with minimum legal mesh size being set to 120 mm for all large mesh trawl fisheries (Søvik et al. 2016). Before 2004, fishing for *Nephrops* was allowed using mesh sizes down to 70 mm, but as *Nephrops* was considered bycatch in a mixed fishery, the special regulations regarding this species were removed. According to the Norwegian fisheries organization, the directed trawl fishery for *Nephrops* in this area disappeared with the 120 mm mesh size legislation. In 2004, trawling inside 4 nautical miles was banned in the Norwegian EEZ of the North Sea.

The minimum landing size (MLS) is 130 mm total length (from tip of rostrum to end of tail) (40 mm CL). Norwegian *Nephrops* landings may consist of up to 10% in numbers below MLS. In the Norwegian EEZ in the North Sea it is illegal to fish with more than two trawls (twin trawls).

A.3. Ecosystem aspects

Nephrops directed trawl fisheries are characterised by large amounts of non-commercial bycatch species and *Nephrops* below MLS. However, in FU 32 *Nephrops* are caught in a mixed fishery where the amount of *Nephrops* below MLS is small due to the legislated mesh size of 120 mm. The *Nephrops* discard mortality from trawl fishing is considered to be high (75%) (Wileman et al. 1999), while it is basically zero in trap fisheries (ICES 1998).

Nephrops are omnivorous and eat crustaceans, molluscs and polychaetes as well as dead and decaying plant and animal matter. Recently, *Nephrops* have been found to ingest plastic strands (Murray and Cowie 2011). *Nephrops* are preyed upon by many species of demersal fish, like cod.

The species occurs south to Marocco, which suggests that it might tolerate increased sea temperatures in the northern part of its distribution range. The 1st quarter mean bottom temperature in FU 32 (from the annual Norwegian shrimp survey) has varied between 6.6 and 8.2 °C in the years 2006-2018 (Thangstad et al. 2017). Salinity has varied between 35.11 and 35.26 ‰ in the same time period.

B. Data

B.1. Commercial catch

Onboard sampling of Danish catches (split into discards and landings components) has been carried out by Danish observers since 1997 (Table B1-1), providing information on length distribution, mean size and sex ratio. For 2008, sex specific data do not exist as the observers pooled data on males and females. For 2009, sex specific data only exist from the discard sampling. Due to changes in the Danish at-sea-sampling programme implemented in 2011, where observer trips were randomly drawn from all fishing trips, only one trip was sampled within FU 32 this year. This was due to the few Danish fishing trips in FU 32. The at-sea-sampling programme was changed in 2012, resulting in a satisfactory number of at-sea-sampling trips.

Onboard sampling of catches as part of inspections (not split into discards and landings components) is carried out by the Norwegian Coast Guard, mainly on Danish trawlers (Table B1-2). Data are available back to 2005. The Coast Guard mainly measures catches by total length (TL) since the MLS is given as TL, and there were no CL data in 2010 or 2013-2016, and very little data in 2005 and 2009.

Since 2003, the Danish at-sea-sampling programme has provided data for discard estimates. Samples have not covered all quarters. There were no discard data for 2008 and 2011. The Danish discard rate is considered unsuitable for estimating Norwegian discards, as the two fisheries take place partially on different fishing grounds and by different gears. As discard mortality from traps is basically zero, the increasing trap fishery and decreasing trawl fishery imply that Norwegian discards in recent years are low. For a description of the Danish sampling programme, see Feekings et al. (2012). Since 2014, advice is based on catches assuming zero discards in the Norwegian fishery.

Table B1-1. Number of observer trips per year by the Danish at-sea-sampling programme in FU 32, total number of hauls with *Nephrops* in the catch on these trips, and number of *Nephrops* in samples of discards and landings. No data were obtained in 1999 and 2001.

Year	Number of trips	Number of hauls	Number of *Nephrops* in discard sample	Number of *Nephrops* in landings sample
1997	4	31	5228	41
1998	1	2	0	204
1999				
2000	2	20	146	3760
2001				
2002	5	38	1849	3125
2003	3	27	2617	3344
2004	5	28	2619	3484
2005	3	23	1565	2108
2006	5	17	1498	2169
2007	6	25	1746	2690
2008	8	45	2492	5489
2009	5	19	598	2030
2010	6	21	1122	2466
2011	1	5	0	384
2012	5	20	1369	2976
2013	7	25	1018	1039
2014	6	32	1601	3864
2015	4	26	809	3204
2016	7	34	1519	3029
2017	3	14	70	103

Table B1-2. Annual number of inspections (catch samples) by the Norwegian coast guard of Danish and Norwegian trawlers with *Nephrops* in the catch, and number of *Nephrops* in the catch samples (split on CL and TL measurements).

Year	Number of CL-samples	Number of TL-samples	Number of *Nephrops* in CL-samples	Number of *Nephrops* in TL-samples
2005	1		118	
2006	12	14	1397	1925
2007	10	7	1345	860
2008	10	18	1462	2899
2009	1	17	182	2386
2010		11		1486
2011	12	24	1856	4323
2012	5	15	401	1538
2013		20		1720
2014		3		213
2015		16		1015
2016		10		589
2017				

B.2. Biological sampling

There are no biological data from this stock.

B.3. Surveys (use the ICES surveys acronym)

A stock size index (biomass) for *Nephrops* in FU 32 is based on data from a bottom trawl survey targeting shrimp (Thangstad et al. 2017). A Campelen 1800/35 bottom trawl with rockhopper gear is used. Mesh size in the cod end is 20 mm. The survey is stratified into nine strata (Figure B3-1) and has a fixed station design.

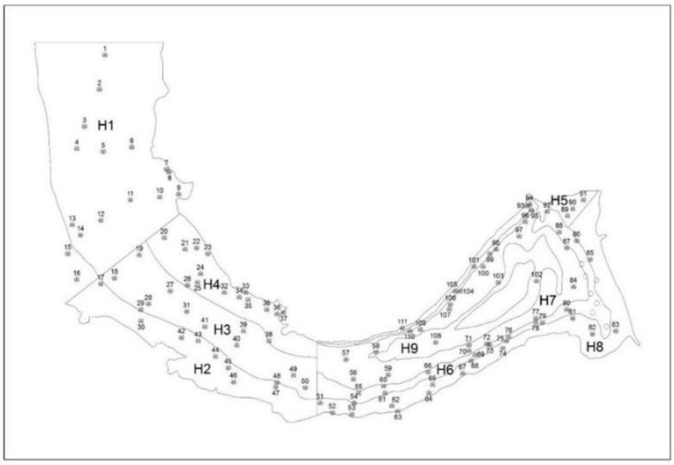

Figure B3-1. Norwegian shrimp survey in the Skagerrak (FU 3) and Norwegian Deep (FU 32): strata system based on depth contours and area.

Estimates of *Nephrops* biomass indices are calculated separately for FU 32 and FU 3. Details are in Annex 2 of ICES (2016).

The distribution of the biomass of individuals (y) in a haul is approximated by a mixed probability function consisting of a binary discrete distribution for zero/non-zero and a continuous distribution, g(y), for the non-zero values:

$$f(y) = \begin{cases} 1-\pi & y=0 \\ \pi \cdot g(y) & y>0 \end{cases}$$

where π is the probability of a positive haul and $\int_{>0}^{\infty} g(y)dy = 1$. The expectation of y, i.e. E(y), equal to $\pi \cdot \overline{g}$, i.e. the probability of getting a positive haul times the mean catch in the positive hauls, is the survey index of mean number for which an estimate is sought; using Bayesian methods for fitting the model makes confidence intervals for these indices more accessible. Two separate General Linear Models (GLM) are constructed to predict, respectively, π and g(y) and define the overall distribution of the data. "Area" (the strata definition, Figure B3-1) and time-of-day (two periods: "light" (0600 to 2000 hrs), "dark" (2000 to 0600 hrs)) are used as explanatory variables taking spatial structure and *Nephrops* diurnal activity behaviour into account, together with a time effect, year, as surveys are conducted on an annual basis.

The GLM model for the occurrence of non-zero hauls

Of ndat hauls taken in day period d in area a in the year t, mdat catch *Nephrops*. The variable mdat is considered to have a binomial distribution with probability parameter πdat:

$$m_{dat} \sim \text{Binomial}\left(n_{dat}, \pi_{dat}\right)$$

Using a logit link function to scale probabilities to effects, the probability π is described as having components:

$$\text{logit}\left(\pi_{dat}\right) = \alpha_{1,t} + \alpha_{2,\text{a}} + \alpha_{3,d}$$

where α1,t is an effect of year t, α2,a is an effect for area a, and α3,d is the effect of day period d.

The GLM model for the abundance of *Nephrops* in non-zero hauls

The density, yitad, in the haul i taken at day period d in area a in the year t with positive catch is modelled by a Generalised Gamma distribution. This model is kept simple by assuming that the distribution of densities has the same shape in all sampling units, i.e. that the CV of density and its skewness are the same, regardless of the mean. This permits fitting common values of kappa and beta, but different values for the mean density, to the year-area-depth combinations, so:

$$y_{itad} \sim gen.gamma(\kappa, \theta_{itad}, \beta)$$

Using a log link the predicted logarithm of mean density is:

$$\mu_{itad} = \gamma_{1,t} + \gamma_{2,\text{a}} + \gamma_{3,d}$$

where γ1,t is an effect of year t, γ2,a is an effect of area a, and γ3,d is the effect of day period d; as for presence-absence.

In applying Bayes's equation to the present problem, the posterior probability distribution of the survey indices is derived by Monte-Carlo-Markov-Chain (MCMC) sampling methods. The programming framework OpenBUGS 3.2.3 provides a means of specifying and analysing a Bayesian model, including selection and implementation of appropriate algorithms.

Uninformative prior distributions for the model parameters are used. The year-area and depth effects, for both presence and density, are given uniform priors (in log space) between – 10 and 10, a range much wider than that of the observed densities. The (approximate) CV of the Generalised Gamma distribution, σ, is given a uniform prior between 0.5 and 4. The shape parameter, λ, is given a distribution uniform in log space between – 4 and the logarithm of the reciprocal of σ. The year, area and the depth effects, parameters in log space, are given prior distributions uniform from -10 to 10. The year, area and day period effects are fitted without weighting the data, which implies assuming that the density of stations is nearly the same in all sampling units.

The survey indices

For each year-area combination the proportion of the area occupied by *Nephrops* is estimated by reversing the logit scaling:

$$P_{t,a} = \frac{\exp(\alpha_{1,t} + \alpha_{2,a})}{1 + \exp(\alpha_{1,t} + \alpha_{2,a})}$$

and the mean density of biomass in the occupied area is estimated by

$$M_{t,a} = \exp\left(\gamma_{1,a} + \gamma_{2,a}\right)$$

so the mean density of *Nephrops* biomass in the area a in year t is Pt,a·Mt,a and the total biomass in area a is Aa·Pt,a·Mt,a where Aa is the extent of area a.

B.4. Commercial LPUE

A landings-per-unit-effort (LPUE) time-series is available from the Danish trawl fleet. The Danish logbooks contain information on catches per vessel, trip, day, and ICES square. Information on gear is not consistent and is often the main gear used by the vessels. There is no information on mesh size. LPUE is estimated using officially recorded effort. Formerly the effort index used was days fished. In 2014, a new effort index was introduced, kW days, in order to account for changes in vessel size with time, which replaces the former GLM-standardization.

Norwegian electronic logbooks compulsory for all vessels ≥ 15 m were introduced in 2011 and contain data on catches per haul, haul position, and both type and number of gear. Large mesh bottom trawl and shrimp trawl can be distinguished based on mesh size (≥ 120 mm and 35-60 mm, respectively) and target species (shrimp vs *Nephrops*/demersal fish). Information on mesh size is lacking in the 2011-2012 logbooks.

Data from bottom trawls prior to 2011 are considered unsuitable for LPUE analyses mainly because a single vessel, with 70-100% of the logbook catches in 2003-2008, had strange recordings of haul duration in 2005-2007 resulting in very high LPUE values (ICES 2013).

The Norwegian data situation in FU 32 has not improved with the introduction of the electronic logbooks, basically because there are so few large Norwegian vessels landing *Nephrops* from this area. The trap fishery is carried out by small vessels, which are not obliged to fill out logbooks. An LPUE index based on the little data in the Norwegian electronic logbooks is considered unrepresentative of the present Norwegian *Nephrops* fishery in FU 32.

C. Assessment: data and method

None

D. Short-Term Forecast

None

E. Medium-Term Forecast

None

F. Long-Term Forecast

None

G. Biological Reference Points

None specified.

H. Other Issues

Since 2015, ICES has provided catch advice for FU 32. Previous, landings advice was given. Advice has previously been given for two scenarios: 1) discarding allowed (the number of dead removals take into account a 25% survival rate of discards); and 2) landing obligation (all catch will be landed), while in 2017 advice was only given for scenario 1). Following the procedure for data poor *Nephrops* stocks (ICES 2015), an estimated guidance of the biomass in FU 32 is provided allowing different harvest rates to be calculated. Using FU area (calculated from information on the extent of *Nephrops* fisheries), UWTV-survey information on mean densities of *Nephrops* (including values of 0.1 animals/m2 from the neighbouring functional unit Fladen Ground (minimum value) and 0.2 animals/m2 from neighbouring functional unit Skagerrak (sub area 7)), mean discard rate from the three last years (Danish discards divided by total catches (zero discards are assumed for the Norwegian fishery)), and mean weight in Danish landings and discards (three last years), a table of harvest rates (Table H-1) is calculated using a range of catches (last 10 years average, 50% of the last 10 years average, and maximum catches observed for the stock).

Discards in Table H-1 are estimated by:

D = {r * (L/wL) * wD} / {1-r},

where D is discards in weight (tons), r is the mean discard rate in numbers (last 3 years), L is total landings in weight (tons), wL is mean weight (g) of Danish landings (last 3 years), and wD is mean weight (g) of Danish discards (last 3 years). For the "discarding allowed" scenario, D was multiplied with 0.75 and 0.25 to estimate dead and live discards respectively, assuming a 25% survival rate of discarded *Nephrops*.

The total area of the *Nephrops* grounds in FU 32 is since 2017 estimated using the spatial distribution of the Danish fishery as the Norwegian trawl fishery has more or less come to an end.

Harvest rates (HR) in Table H-1 (dead removals divided by total numbers in the stock) are estimated by:

HR = {L * 1,000,000 / wL + D * 1,000,000 / wD } / {d * a * 1,000,000},

where d is density (animals/m2) of *Nephrops* and a is the spatial distribution (km2) of the Danish fishery in FU 32.

Table H-1. Template table for calculating a range of harvest rates for *Nephrops* in FU 32.

Landing obligation												
Basis	**Total catch**	**Wanted catch**	**Unwanted catch**	**0.05**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
0.5 * Average	C	L	D	%	%	%	%	%	%	%	%	%
Average	C	L	D	%	%	%	%	%	%	%	%	%
Maximum	C	L	D	%	%	%	%	%	%	%	%	%
					FU 7 density	**FU 3 density**						

I. References

Feekings, J., Bartolino, V., Madsen, N. and Catchpole, T. 2012. Fishery Discards: Factors Affecting Their Variability within a Demersal Trawl Fishery. PlosOne 7(4): 1-9. doi:10.1371/journal.pone.0036409.g001.

Frandsen, R., Eliasen, S.Q., Lövgren, J., Søvik, G., Feekings, J.P., Ulmestrand, M., Lund, H., Andersen, B.S., Axelsen, B.E., Bastardie, F., Berg, C.W., Bichel, N., Furevik, D., Jacobsen, J.B., Johansen, T., Jonasdottir, S., Jonsson, P., Jørgensen, T., Karlsen, J.D., Kleiven, A.R., Løkkeborg, S., Lundgren, B., Madsen, N., Munch-Petersen, S., Nielsen, A., Nielsen, J.R., Reeh, L., and Westgaard, J-I. 2015. Sustainable development of the Nephrops fishery in the Kattegat-Skagerrak region. DTU Aqua report no. 298-2015, 212 pp.

ICES. 1998. Nephrops survival after escape from commercial fishing gear or discarded from deck. Fishing Technology and Fish Behaviour Working Group (WGFTFB), La Corũna, Spain, 20-23 April, 1998.

ICES. 2013. Report of the Benchmark Workshop on Nephrops Stocks (WKNEPH). 25 February-1 March 2013 Lysekil, Sweden. ICES CM 2013/ACOM: 45. 183 pp.

ICES. 2015. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) 28 April – 7 May 2015, Copenhagen, Denmark. ICES CM 2015/ACOM: 13. 1047 pp.

ICES. 2016. Report of the Benchmark Workshop on Nephrops Stocks (WKNEP), 24–28 October 2016, Cadiz, Spain. ICES CM 2016/ACOM:38. 223 pp.

Murray, F. and Cowie, P.R. 2011. Plastic contamination in the decapods crustacean Nephrops norvegicus (Linnaeus, 1758). Marine Pollution Bulletin 62(6): 1207-1217.

Søvik, G., Furevik, D., Jørgensen, T., Bakke, S, Larssen, W.E., Thangstad, T.H. and Woll, A.K. 2016. The Norwegian Nephrops fishery – history, exploitation and management. In: Thu, B.J. and Gundersen A.C. (eds.). Sustainable bio-resources. Management, product development and raw material quality. Orkana Akademisk, Stamsund, pp: 95-118. ISBN 978-82-8104-290-2.

Thangstad, T.H., Søvik, G., Gabrielsen, H., Henriksen, I., Karlsen, K. E., Kvalsund, M. og Vedholm, J. Reketokt i Norskerenna og Skagerrak januar 2017. Toktrapport/Havforskningsinstituttet/ISSN 1503 6294/Nr. 1 – 2018. 65 pp.

Wileman, D.A., G. I. Sangster, M. Breen, M. Ulmestrand, A. V. Soldal and R.R. Harris, 1999. Roundfish and Nephrops survival after escape from commercial fishing gear. EC Contract No: FAIR-CT95-0753. Final Report 1999. 125 p + appendix.