Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 4.b, Functional Unit 6 (central North Sea, Farn Deeps)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster
Working Group:	Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
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A. General

A.1. Stock definition

Throughout its distribution, *Nephrops* is limited to muddy habitat, and requires sediment with a silt & clay content of between 10–100% to excavate its burrows, and this means that the distribution of suitable sediment defines the species distribution. Adult *Nephrops* only undertake very small-scale movements (a few 100 m) but larval transfer may occur between separate mud patches in some areas. In the Farn Deeps area the *Nephrops* stock inhabits a large continuous area of muddy sediment extending North from 54°45′–54°35′N and 0°40′–1°30′N with smaller patches to the east and west.

The extent of the mud covers the following statistical rectangles:

38–40 E8–E9; 37E9 and the assessed ground is defined by a polygon which encompasses suitable sediment and known fishing tracks (from VMS) as shown in Figure B1.1.0

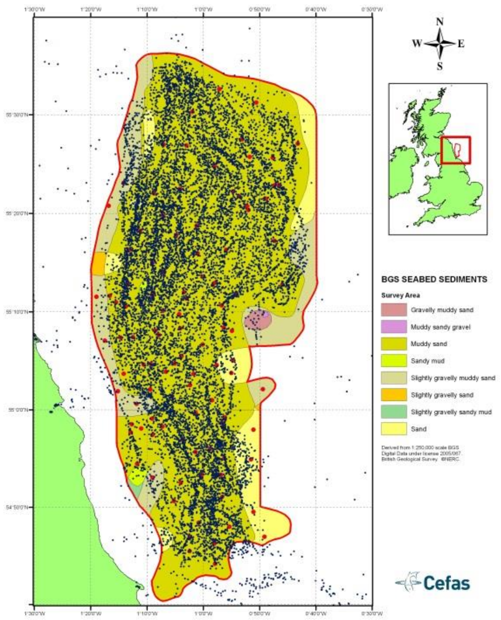

Figure B 1.1.0. Definition of Farn Deeps assessment area.

A.2. Fishery

The *Nephrops* fishery in the Farn Deeps is largely a winter fishery, starting usually in October and extended to March. This fishing pattern has been quite stable over the last 30 years where 80% of the landings occurred in this period. Occasionally, some seasons can shift a bit, having early or later start/endings.

The fleet targeting *Nephrops* in this ground is composed by local vessels (mostly single rigs) and visitors from Scotland (mainly twin rigs), less from Northern Ireland and occasionally form the Netherlands. In the past *Nephrops* was target mainly using single rigs but the proportion of landings from twin trawlers has increased gradually since the 1990s. From 2008 the proportion of landings taken by the twin rigs stabilized, accounting with 40% of the landings.

Over 25% of the entire fleet uses multi rigs mainly through an influx of up to 19 Northern Irish and 30 Scottish multi riggers visiting the area.

Fishing by the 'local' vessels is usually limited to a trip duration of one day with two hauls of 3–4 hours being carried out. The larger vessels tend to make trips of between three and seven days with tows of around five hours. The main landing ports are North Shields, Blyth, Amble and Hartlepool where respectively, 50, 29, 11 and 7% of the landings from this fishery are made (average 2003–2012).

In 2001 the cod recovery plan was introduced and the number of vessels recorded in this fishery and landing into England increased from around 160 in 2000 to and fluctuating around 200 between 2001 and 2003. In 2004 the number returned to around 160 vessels but stepped up to 230 vessels in 2006, and then decreasing back to more historical levels. Although a small increase was apparent in the number of the local fleet turning to *Nephrops* the increase in the number of visiting Scots, Northern Irish and other English vessels was greater. Visiting Scottish vessels consistently make up about 30 to 40% of the fleet during the season and account for between 20 and 30% of the landings by weight. Both single and multi-trawl fleets were affected by Technical Conservation Measures and Cod recovery plans. The single-trawl fleet in general switched from a 70 mm to an 80 mm codend mesh in 2002. Twin and multi-rigged vessels targeting prawns use 95 mm codend mesh. The average vessel size of the visitors has remained relatively stable but average horse power has increased. With decommissioning the average size and power of the local fleet has declined slightly. Currently the average size of the local fleet is 11 m with an average engine power of around 140 kW.

The minimum landing size for *Nephrops* in the Farn Deeps is 25 mm CL. Discarding generally takes place at sea, and in the past it was usually continued alongside the quay. From 2008–2009 there was a big reduction of sorting at the quay side and nowadays this practice is considered sporadic. Landings are usually made by category for whole animals, often split into "large" and "medium" categories with a further category for "tails". However, landings to merchants of one category of unsorted whole and occasionally one of tails is becoming more common.

Regulations

UK legislation (SI 2001/649, SSI 2000/227) requires at least a 90 mm square mesh panel in trawls from 80 to 119 mm, where the rear of the panel should be not more than 15 m from the codline. The length of the panel must be 3 m if the engine power of the vessel exceeds 112 kW, otherwise a 2 m panel may be used. Under UK legislation, when fishing for *Nephrops*, the codend, extension and any square mesh panel must be constructed of single twine, of a thickness not exceeding 4 mm for mesh sizes 70–99 mm, while EU legislation restricts twine thickness to a maximum of 8 mm single or 6 mm double. In addition to these conventional gears, due to the cod long-term management plan (Regulation (EC) No 1342/2008), English vessels, over 10 m, landing more than 5% cod, must use a gear that catches less than 1.5% cod for 20 fishing days (can be split ten plus ten consecutive days) when fishing N of 55 (which bisects the Farn Deeps *Nephrops* fishery). Scottish vessels must use a 'Highly Selective Gear' ("selectivity" referring to lower efficiency for finfish rather than size selectivity for *Nephrops*) for the whole fishing year but these gears show no change in their selectivity for *Nephrops*. It is thought that options for Highly Selective Gear may be given to the English fleet to compliment the use of the grid. The differential in technical measures in force across the ground may affect the length composition of catches.

Under EU legislation, a maximum of 120 meshes round the codend circumference is permissible for all mesh sizes less than 90 mm. For this mesh size range, an additional panel must also be inserted at the rear of the headline of the trawl. UK legislation also prohibits twin or multiple-rig trawling with a diamond codend mesh smaller than 100 mm in the North Sea south of 57°30′N. Scottish legislation prohibits Scottish vessels from using multiple (>2) rig trawls in all UK waters.

Under the common fisheries policy (CFP) reform the discard ban will became effective for *Nephrops* from 2015.

A.3. Ecosystem aspects

No information on the ecosystem aspects of this stock has been collated by the working group.

B. Data

B.1. Commercial catch

Three types of sampling occur on this stock, market sampling (landings), on-board observer sampling (discard and retained samples) and the *Nephrops* catch sampling programme which provides monthly samples during the fishing season (typically October–March) covering North Shields, Blyth, Amble and Hartlepool fishing ports. This catch sampling programme provides information on *Nephrops* size distribution, sex ratios, weight–length and maturity.

Years prior to 2002

Historically, estimates of discarding were made using the difference between the catch samples and the landings samples. For the period prior to 2002, catch length samples and landings length samples are considered to be representative of the fishery.

An estimate of retained numbers-at-length was obtained for this period from the catch sample using a discard ogive estimated from data from the 1990s, a raising factor was then determined such that the retained numbers-at-length matched the landings numbers-at-length. This raising factor was then applied to the estimate of discard numbers-at-length.

2002–current

The market sampling data have not been used in the raising process since 2008. There was concern that the ratio between samples of tails and whole animals was not in the same proportion as was coming ashore (tails were underrepresented in the samples). This was thought to be inducing bias in the resulting length frequencies.

On-board discard sampling has been of sufficient frequency since 2002 to allow the estimation of discards from these data. As with the landings sampling, the practice of tailing causes some sampling issues, although with the observer data it is not thought to be an insurmountable problem. Historically there have been are two modes of operation for “tailing” in the FU6 *Nephrops* fishery, some vessels tailing at sea, others tailing at the quayside although quayside tailing has virtually ceased since around 2010. Observer records of "discards" are only made when active discarding practice is observed, hence on occasions where the catch was left to be sorted (and tailed) at the quayside, an observer sample would record all individuals as "retained", although this may contain individuals well below MLS. Figure B.1.1 shows the frequency distribution of discarding practice below MLS and there is a clear spike of 0% discarding. Inclusion of these samples in the discard estimation process would induce significant bias and therefore samples with less than 20% discarding observed below MLS are ignored in subsequent processing.

Annual discard ogives demonstrated no systematic change, therefore a single ogive was constructed from the pooled data from 2002–2010 (Figure B.1.2). This was then applied to the catch data to produce estimates of landings-at-length.

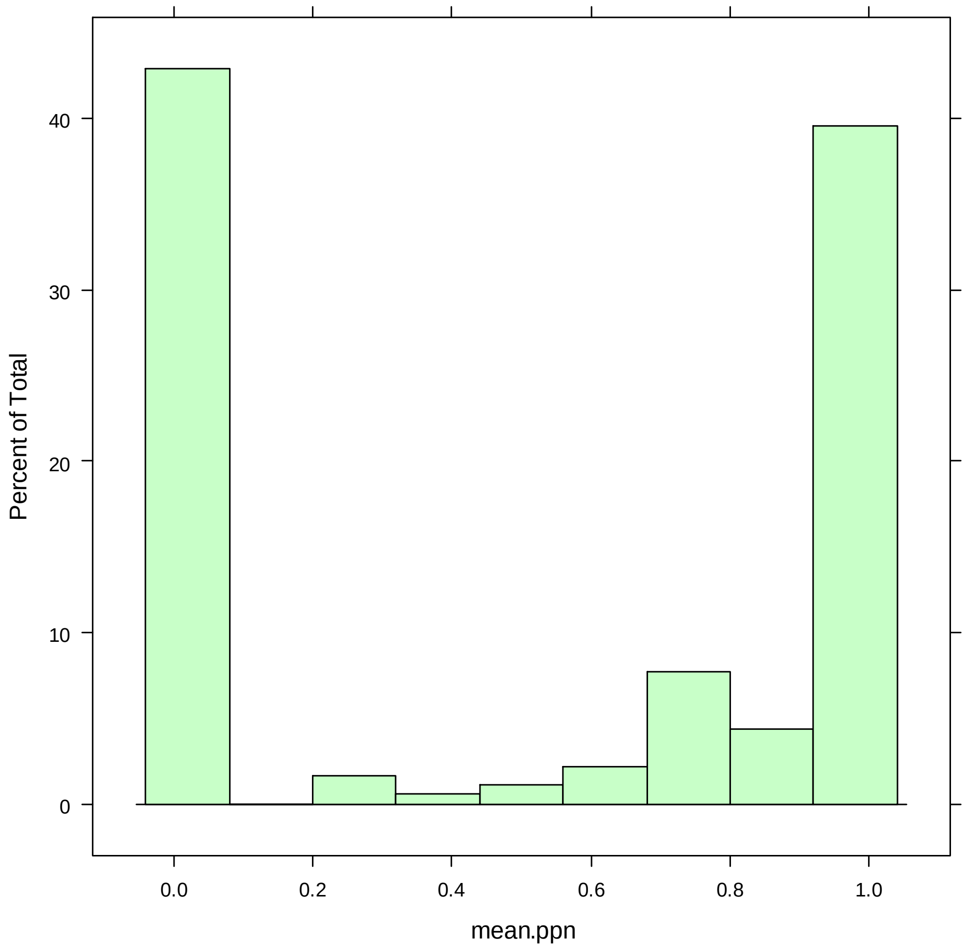

Figure B.1.1. Farn Deeps (FU 6): Histogram of proportion individuals <26 mm discarded.

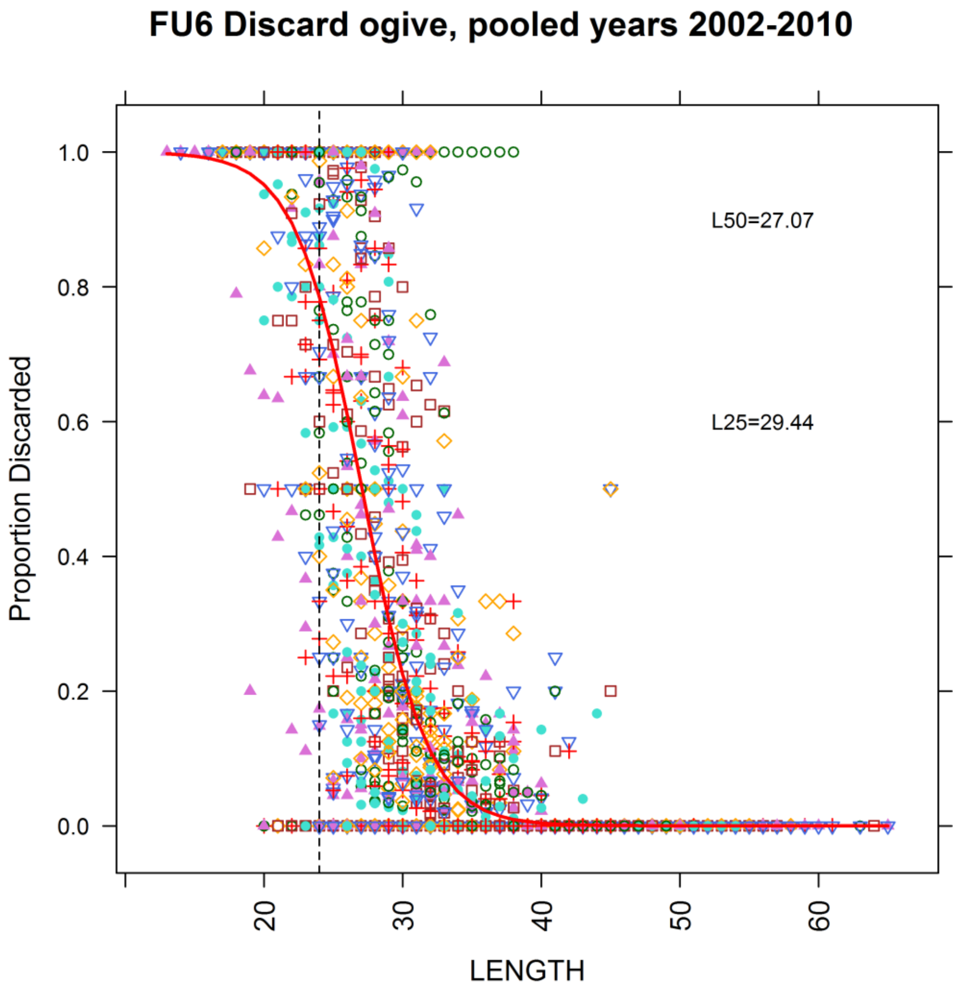

Figure B.1.2. Farn Deeps (FU 6): Discard ogive selected for FU6 *Nephrops*, trip level data spanning 2002–2010.

B.2. Biological

Growth

Growth parameters presented in WK*NEPH* 2009 were estimated by Macer (unpublished data) from observations of the Farn Deeps fishery and comparison with adjacent stocks. No changes were made in these parameters at WK*NEPH* 2013.

Length–weight

Prior to 2011 weights-at-length for this stock were estimated from a fixed weight–length relationship derived from samples collected from this fishery (Macer, unpublished data).

At WK*NEPH* 2013 length–weight data were reviewed. These data have been collected monthly during the *Nephrops* catch sampling programme (during the fishing season) since 1984. Length–weight relationships have been reasonable stable during the time-series and so the updated parameters presented in WK*NEPH* 2013 were calculated from the pooled data 2010–2012 for both males and females.

Maturity

	Female			Male	
	Function	L25	L50	Function	L50
2004	Knife-edge		24.0	Knife-edge	26.7
2006	Knife-edge		24.8	Knife-edge	25.8
2009	Sigmoid	24.5	25.0	Knife-edge	29.8
2013	Sigmoid	27.2	30.5	Knife-edge	25.2

The size-at-maturity for females was recalculated at ICES WK*NEPH* 2006 to be 24.8 mm CL. 24 mm CL was used in assessments prior to 2009. The sigmoid maturity function used at WK*NEPH* 2009 estimate L25 = 24.5 mm and L50 = 25 mm.

At WK*NEPH* 2013 maturity data available from the *Nephrops* catch sampling programme was review and estimates of the L50 were obtained for females since 1985 (visual examination of the ovaries and/or egg bearing condition, using Symmonds stages up to 2004 and using Redant stages from September 2004 onwards, Table 2). Maturity stages were harmonized to compare the entire dataset.

Natural mortality

A natural mortality rate of 0.3 was assumed for males (Morizur, 1982) and immature females, with a value of 0.2 for mature females. The lower value for mature females reflects the reduced burrow emergence while ovigerous and hence an assumed reduction in predation. No changes in these parameters were made at WK*NEPH* 2013.

***Nephrops* discard survival**

Year	Survival
<1991	25%
1991	0%
2013	15%

Before 1991, *Nephrops* discard survival was assumed to be 25%, however in 1991 it was set to zero on the basis that most sorting occurred whilst the vessel was steaming back to port and the discarded prawns would be likely to fall on unsuitable ground.

The discard survival was reviewed in 2013 on the basis that the discarding practice changed since 2008–2009, from where local vessels started to sort most of the catch while at sea, discarding at suitable *Nephrops* grounds. As well the increase of big vessels in this ground, which can spend several days at sea, also increased the discarding of *Nephrops* in suitable grounds. Additionally, due to the nature of this winter fishery, the temperature shock can be considered low and so favour the survival rate. Based on these facts the survival rate was updated to 15% although it has minimal effect upon the MSY proxies.

Summary

Growth

Males; $L\infty$ = 66 mm, k = 0.16

Immature Females; $L\infty$ = 66 mm, k = 0.16

Mature Females; $L\infty$ = 58 mm, k = 0.06,

Maturity parameters

Size-at-maturity females (pool data 2010–2012, catch sampling programme):

L_{25}=27.16 (SE: 0.333) mm, L_{50}=30.48 (SE: 0.261) mm.

Weight–length parameters (pool data 2010–2012, catch sampling programme)**:**

Males a = 0.00048, b = 3.112 (Residual SE: 0.1361; Multiple R-squared: 0.9628)

Females a= 0.00111, b = 2.850 (Residual SE: 0.09819; Multiple R-squared: 0.9795)

Discards

Discard survival rate: 15%

Discard proportion: 29.5%

B.3. Surveys

Abundance indices are available from the following research-vessel surveys:

Underwater TV survey: years 1996–present. Surveys have been conducted in spring and/or autumn each year but only consistently in autumn from 2001. In 2008 there was an historical revision of burrow density estimates from the TV survey. Previous estimates of burrow density had assumed that station density was independent of burrow density based analysis that showed there was no evidence of differences in trends in burrow density between the different strata in the fishery (ICES WGNEPH, 2000). The assumption led to an unstratified mean density being used and multiplied by the total area to arrive at overall abundance. Analysis of burrow density by rectangle has since shown that the distribution of stations is positively correlated with burrow density and therefore the unstratified mean density will overestimate burrow density. In order to compensate for the bias in sampling density, burrow abundance estimates are made for each rectangle and then summed to give the new total.

The procedure was revised again in 2011 and a geostatistical approach was taken, working the survey data back to 2007 in order to completely remove the bias between station density and burrow density. The procedure is run using the R statistical package with the gstat, maptools, and spatstat libraries.

A boundary file was created using the VMS and BGS sediment data on the MapInfo GIS system and is used to delimit the boundaries of the kriged map.

Mean density per station and the geographical coordinates (transformed from latitude and longitude into metres displacement from 54.67275 N, -1.332769 E) are first fitted with a variogram model. The following commands are used to fit the variogram (the data are held in dataframe “recounts7”).

```
gstat.recount <- gstat(id="BurrowDensity",formula=BurrowDensity~1, loca-
tions=~lon.m+lat.m, data=recounts7)
vario.recount <- variogram(BurrowDensity~1 , locations=~lon.m+lat.m, data=re-
counts7)
fit.vario.recount <- fit.variogram(vario.recount, model=vgm(0.1, "Exp", 15000,
0.03))
plot(vario.recount, fit.vario.recount)
```

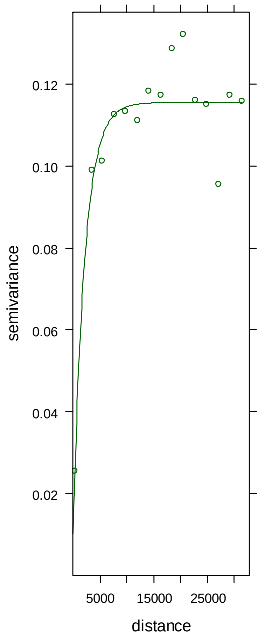

Figure 1.

A kriged estimate of density is then produced for a 500*500 m grid of points lying inside the boundary with the following code.

```
coordinates(recounts7)=~lon.m+lat.m

#and the grid we're going to produce
pred.lat <- seq(from=y.range[1], to=y.range[2], by=500)
pred.lon <- seq(from=x.range[1], to=x.range[2], by=500)

recount.grid <- data.frame(lat.m=rep(pred.lat, each=length(pred.lon)),
lon.m=rep(pred.lon, times=length(pred.lat)))
pos <- point.in.polygon(recount.grid$lon.m, recount.grid$lat.m, bound-
ary$dist.lon, boundary$dist.lat)
recount.grid <- recount.grid[pos>0,]
gridded(recount.grid)=~lon.m+lat.m

coordinates(boundary)=~dist.lon+dist.lat

#krig it
krige.recount <- krige(BurrowDensity~1, recounts7, recount.grid,
model=fit.vario.recount)
res <- (sum(krige.recount$var1.pred*250000)/1000000) /bias

# each cell represents a 500m*500m block = 250000 sq m, divide by 1million to
get the index in millions
```

By bootstrapping the recount data with replacement it is possible to estimate the uncertainty on the survey abundance estimate. Typically this comes out at a ~2% confidence interval.

UWTV relative to absolute conversion factors

A number of factors are suspected to influence the ability of the surveys to map directly to absolute abundance.

Time period	Edge effect	detection rate	species identification	occupancy	Cumulative Absolute Conversion Factor
<=2009	1.3	0.85	1.05	1	1.2

B.4. Commercial cpue

Catch-per-unit-of-effort time-series are derived from the recorded effort for English vessels using gears 7, 13, 14, 15 and 96 (unspecified otter, *Nephrops*, twin-*Nephrops*, triple *Nephrops* and quad-*Nephrops* gears), using mesh in the range of 70–99 mm is used in conjunction with their reported landings.

There is no account taken of any technological creep in the fleet.

The registered buyers and sellers legislation brought in by the UK in 2006 changed the reporting procedure, which effectively breaks the continuity in the series at that point. The accuracy of the reported landings has significantly improved since then but there is currently little that can be done to determine and correct for any differences in the two series.

Advice Generation Protocol

1) Survey indices are worked up annually resulting in the TV index.

2) Apply the Absolute Conversion Factor (see Section B3). The combined effect of these biases is to be applied to the new survey index.

3) Generate mean weight in landings. Check the time-series of mean landing weights for evidence of a trend in the most recent period. If there is no firm evidence of a recent trend in mean weight use an average taken over an appropriate time-scale. If, however, there is strong evidence of a recent trend then apply most recent value (don't attempt to extrapolate the trend further in future).

4) The catch option table will include the harvest ratios associated with fishing at $F_{0.1}$, $F_{35\%SpR}$ and F_{MAX}. These values are estimated by Benchmark Workshops (ICES, 2013) but may be revised if there indications of changes to fishery or biological factors.

5) Create catch option table on the basis of a range of harvest ratios ranging from 0 to the maximum observed ratio or the ratio equating to F_{MAX}, whichever is the larger. Insert the harvest ratios from step 4 and also the current harvest ratio.

6) Multiply the survey index by the harvest ratios to give the number of total removals.

7) Create a landings number by applying the discard ratio.

8) Produce landings biomass by applying mean weight.

Biological reference points

Harvest ratios equating to fishing at $F_{0.1}$, $F_{35\%}$ spawner per recruit and F_{MAX} were calculated in WK*NEPH* (2009) and subsequently revised by WGNSSK 2011 and

WKNephBench 2013. These calculations assume that the TV survey has a knife-edge selectivity at 17 mm (ICES 2009, 2013 Section 3) and that the supplied length frequencies represented the population in equilibrium.

Harvest ratios were reviewed in 2013 with the new updated parameters. The value used for the F_{MSY} proxy is $F_{35\%}$ males. The rationale behind this is that the fishery is traditionally strongly skewed towards males, which causes the SpR of males to fall below 25% when the "default" $F_{35\%}$ combined target is used.

The software used to determine the reference points is the Separable Cohort Analysis model as described in Annex 5 of the 2009 *Nephrops* benchmark meeting.

2013 values

		Fbar 20–40 mm		Harvest Rate	% Virgin Spawner per Recruit	
		Female	Male		Female	Male
F0.1	Comb	0.09	0.18	9%	47.52%	32.11%
F0.1	Female	0.16	0.33	14%	32.63%	18.26%
F0.1	Male	0.07	0.14	7%	53.02%	38.50%
F35%	Comb	0.12	0.24	11%	39.98%	24.50%
F35%	Female	0.17	0.37	15%	34.82%	16.64%
F35%	Male	0.16	0.08	8%	57.17%	34.88%
FMAX	Comb	0.17	0.37	15%	34.58%	16.48%
FMAX	Female	0.29	0.61	22%	22.22%	9.47%
FMAX	Male	0.12	0.26	12%	44.70%	23.73%

2011 values

		F_{bar} 20–40 mm		Harvest Rate	% Virgin Spawner per Recruit	
		Female	Male		Female	Male
$F_{0.1}$	Comb	0.05	0.16	7.21%	67.46%	36.61%
$F_{0.1}$	Female	0.11	0.34	12.68%	48.97%	20.18%
$F_{0.1}$	Male	0.05	0.14	6.38%	70.80%	40.61%
$F_{35\%}$	Comb	0.10	0.30	11.46%	52.56%	22.75%
$F_{35\%}$	Female	0.21	0.62	18.74%	34.84%	12.13%
$F_{35\%}$	Male	0.06	0.18	8.00%	64.42%	33.29%
F_{MAX}	Comb	0.11	0.32	12.08%	50.70%	21.39%
F_{MAX}	Female	0.23	0.69	20.02%	32.51%	11.06%
F_{MAX}	Male	0.08	0.23	9.47%	59.08%	28.12%

2009 values for comparison

		F_{bar} 20–40 mm		Harvest Rate	% Virgin Spawner per Recruit	
		Female	Male		Female	Male
$F_{0.1}$	Comb	0.06	0.17	8.20%	63.00%	38.60%
$F_{0.1}$	Female	0.12	0.33	14.20%	45.60%	22.20%
$F_{0.1}$	Male	0.05	0.15	7.10%	67.10%	43.50%

$F_{35\%}$	Comb	0.11	0.3	12.90%	48.90%	24.80%
$F_{35\%}$	Female	0.18	0.5	19.40%	35.00%	14.80%
$F_{35\%}$	Male	0.07	0.2	9.30%	59.50%	34.80%
F_{MAX}	Comb	0.11	0.3	13.20%	48.30%	24.30%
F_{MAX}	Female	0.19	0.51	19.90%	34.30%	14.40%
F_{MAX}	Male	0.09	0.24	10.90%	54.60%	29.90%

$B_{trigger}$ definition

The TV abundance estimate for 2007, the first year of low stock abundance and concern over recruitment is used as MSY $B_{trigger}$. Using the geostatistical method of estimating abundance this equates to an abundance of 802 million individuals over 17 mm carapace length.

References

Morizur, Y. 1982. Estimation de la mortalité pour quelques stocks de langoustine, *Nephrops norvegicus*. ICES CM 1982/K:10.