Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 7.a, Functional Unit 14 (Irish Sea, East)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Norway lobster
Working Group	Working Group for the Celtic Seas Ecoregion (WGSCE)
Authors	Assessment of Northern Shelf Demersal Stocks
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A. General

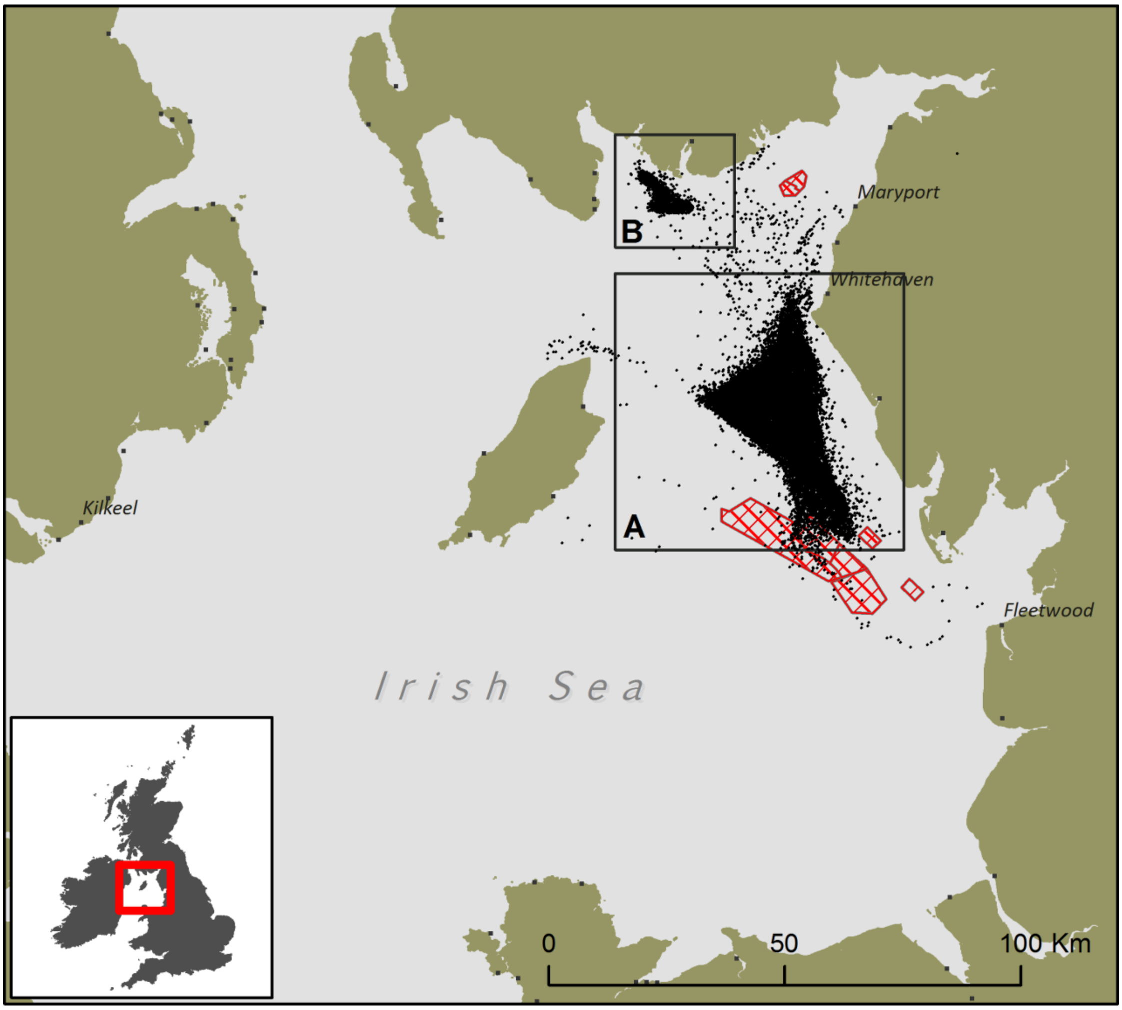
A.1. Stock definition

The Irish Sea East *Nephrops* stock (FU14) is in ICES Subarea 7, more specifically in Area 7.a which also includes the Irish Sea West (FU15) stock.

Throughout its distribution, *Nephrops* is limited to muddy habitat, and requires sediment with a silt & clay content of between 30–100% 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 eastern Irish Sea, the *Nephrops* stock inhabits an area of muddy sediment extending along the Cumbria coast, and its fishery contributes to less than 10% of overall Irish Sea landings. There is little evidence of mixing between the east and west Irish Sea stocks due to the nature of water current movements in the Irish Sea. The two are treated as separate populations since they have different population characteristics.

FU	Name	ICES Divisions	Statistical rectangles
14	Irish Sea East	7.a	35–38E6; 38E5

In FU14 *Nephrops* are caught on two spatially discrete grounds. Most of the fishery takes place in a main ground located between the west coast of England and Island of Man, additionally there is also fishing activity in a small inshore ground know by Wigtown Bay.



East Irish Sea fishing grounds: A= Main fishing ground; B= Wigtown bay area. Windfarms represented by red polygons. Main landing ports: Whitehaven, Fleetwood, Maryport and Kilkeel.

A.2. Fishery

Between 1999 and 2003 the number of vessels fishing for *Nephrops* in FU14 declined by 40% to a fleet of around 50 vessels. This was largely due to the reduction in the number of visiting UK vessels and the decommissioning of part of the Northern Irish and local English fleets. After that period there was a considerable increase up to around 90 vessels in 2009, but since then the number of vessels fishing the area decreased again, being currently less than 50 vessels (2014 data), mainly from England and Northern Ireland. Currently, around 30 of these vessels, between 6 and 23 m in length, have their 'home' ports in Whitehaven, Maryport and Fleetwood, England. The rest of the fleet is generally made up of larger vessels from Kilkeel or Portavogie, Northern Ireland.

Between 1987 and 2006, landings from FU14 appeared relatively stable, fluctuating around a long-term average of about 550 t. Landings in 2007 rose significately (959 t) reaching maximum values since 1978, this is after landings dropped in 2003 to their lowest apparent level since 1974. The following years 2008 and 2009 figures of 676 and 708 t respectively kept high comparing with any other figures recorded since 1990. Recently (2012–2014), landings went back to historical values, averaging 568 t. Although, the introduction of the buyers and sellers legislation in 2006 really precludes direct comparison with previous years as reporting levels are considered to have significantly improved since.

Over the last ten years (2005–2014) UK vessels have landed, on average, 94% of the reported annual international landings. Republic of Ireland vessels increased their share of the landings to 35% in 2002 but it has since declined to 6% (average 2005 to 2014). Between the period 2003–2010 most of the landings were made by visiting Northern Irish vessels (60% of the total international landings), since then England gets the high proportion of the total landings made in FU14 (67%, 2011–2014).

During the years 2010 and 2011, the Walney (UK) Offshore Windfarms Ltd. has constructed the Walney 1 and Walney 2 offshore windfarms, located approximately 15 km off Walney Island, Cumbria, in the Irish Sea. Those started operating at the beginning of 2012, these two offshore windfarms were the world's largest offshore windfarms ever installed with a total capacity of 367.2 MW. The windfarm location site covers an area of what is acknowledged to be extremely good trawling ground for both *Nephrops* and whitefish. In the past this area has been fished by vessels from Fleetwood, Cumbrian ports and Northern Ireland, but during the windfarm construction this area was closed to fishing. Nowadays, there is an exclusion zone around each wind turbine, but fishing is now allowed in the overall area.

The impact of the construction of Walney (UK) Offshore Windfarms Ltd. was analysed during the inter-benchmark process in 2015 (ICES, 2015). The windfarm has impacted fishing behaviour and it is evident that since the construction of the windfarm there has been some effort displacement into Wigtown Bay and the overall fishing area changed in the main ground. The redefinition of the main polygon resulted in a 6% decrease for the main area, from 1032.75 Km^2 to 1019.79 Km^2, although in total due to the increase of Wigtown Bay the total FU14 fishing area is still very similar, from 1052.37 Km^2 to 1087.01 Km^2.

Prior to the construction, there were only two years of UWTV data for this part of the ground which confirmed presence of *Nephrops* with estimated densities to be lower than 0.4 burrows per m^2. The impact in the population abundance cannot be currently estimated, as there are no survey data within the windfarm area.

Regulations

Regulations introduced as part of a revised package of EC Fisheries Technical Conservation measures in 2000 remain in place. This legislation incorporates a system of 'mesh size ranges' for each of which has been identified a list of target species. In effect, nets in the 70–79 mm mesh size range must have at least 35% of the list of target species (which includes *Nephrops*) and the 80–99 mm mesh size range requires at least 30% of the list of target species. A square mesh panel (SMP) of 80 mm is required for 70–79 mm nets in the Irish Sea. Vessels using twin-rig gear in the Irish Sea must comply with a minimum mesh size of 80 mm (no SMP is required for nets with 80 mm meshes and above).

As well as an Area 7 TAC other *Nephrops* conservation measures in the Irish Sea are a minimum landing size of 20 mm CL length (equivalent to 37 mm tail length or 70 mm total length).

In addition to *Nephrops* measures the cod spawning areas of the Irish Sea are closed to whitefish directed vessels between 14th February to 30th April part of the Irish Sea cod recovery plan. There is derogation for *Nephrops* vessels during this closure.

A.3. Ecosystem aspects

The Working Group has collated no information on the ecosystem aspects of this stock.

B. Data

B.1. Commercial catch

During the IBPNeph 2015, a review of commercial catch data and raising procedures was done.

Historically, sampling biological data are only supplied by UK-England. The sampling intensity for this area has been quite low, being almost inexistent during 2010, 2011 and 2012. Numbers of samples increased again in 2013, when the *Nephrops* sampling programme was reinstated by Cefas. In 2016 and 2017, biological sampling data were also supplied by UK Northern Ireland. This was discussed at WGCSE 2018, and it was agreed to revise raising procedures on InterCatch. UK England catch was raised to UK England sampling, UK Northern Ireland catch was raised to UK Northern Ireland sampling and other catch was raised to combined UK England and Northern Irish sampling. With 2015, not including UK Northern Irish sampling, the year's sampling was considered inconsistent to that of 2016 and 2017 and a two-year reference period (2016–2017) was used for the 2018 assessment.

There were identified three sampling programmes that collected biological information for *Nephrops* in the East Irish Sea: *Nephrops* catch sampling (catch component-1999 to current); Observer programme (retain and discard component, 2003 to current); Market sampling (landings component, 1983 to current). Results were discussed at WGCSE 2015, and it was agreed that the market sampling data would not be suitable to raise the total landing data as they are biased towards the bigger size classes, thus on this basis, the observer programme was combined with the catch sampling programme to derive the annual landing length distribution. Mean weight and sizes for landings and discards where updated retrospectively up to 2000. Sex ratio was also updated showing currently a very even exploitation pattern between sexes (proportion of males =0.48 (average 2013–2014)). A single discard ogive was fitted, by pooling all years (2003–2014) and mesh sizes, showing a final discard selection for the East Irish Sea at L50= 23.54 and a L25=24.77 mm CL and the discard selection survival rate was updated to 10% (ICES, IBPNeph 2015).

- At WGCSE 2015, it was agreed that the market sampling data would not be suitable to raise the total landing data as they are biased towards the bigger size classes. The catch sampling programme and the observer programme were combined to provide length and sex composition for the annual landings in FU14. A comparison was done between these two programmes and no clear differences were found in the length distributions between these programmes.
- A threshold of a minimum of 50 animals measured per sample is used to discard any samples with very low measurements.
- Data from the catch sampling programme are partitioned into landings and discards using a discard selection ogive derived from the discard samples provided by the observer programme.
- Sampling effort is stratified quarterly, but an annual aggregation is used to derive the annual landing length distribution.
- Effort and lpue series are now given in KW days for UK directed *Nephrops* fleet.

Discard selection was revised at the IBP process in 2015 (ICES, 2015). There are annual variations but there is nothing systematic and it is assumed that this is sample variation due to the low sample numbers rather than genuine annual changes in selection at length, thus a single discard ogive was fitted by pooling all years (2003–2014) and mesh sizes. Final discard selection for the East Irish Sea shows a L50= 23.54 and a L25=24.77 mm CL (Figure 4.3.34), which shows a selectivity at higher sizes compared with FU15.

B.2. Biological

Mean weights-at-age for this stock are estimated from studies by Bailey and Chapman, 1983.

A natural mortality rate of 0.3 was assumed for all age classes and years for males 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.

The time-invariant values used for proportion mature-at-age are: males age 1+: 100%; females age 1: 0%; age 2+: 100%. The source of these values is not known.

Proportion of F and M prior to spawning was specified as zero to give estimates of spawning–stock biomass at January 1. In the absence of independent estimates, the mean weights-at-age in the total catch were assumed to represent the mean weights in the stock.

B.3. Surveys

Abundance indices are available since 2008 onwards.

The first ever trials of the UWTV surveys in this ground were done in the 1990s (1997 and 1998) but with limited success due to weather conditions. Was only in 2007 where the UWTV surveys started to be conducted regularly. These collaborative surveys occur annually in August with the input of Northern Ireland, Ireland and England. This survey covers both West and East Irish Sea (FU15 and FU14) and is done on board the northern Irish research vessel "Corystes".

In the East Irish Sea (FU14) the survey is of a fixed grid design (3.4 x 3.4 nm) and is carried out using the same protocols used in UWTV surveys in the Western Irish Sea. This FU is composed by a main ground, east of the Isle of Man, and another stretch in Wigtown Bay (North of Isle of Man). The survey design is documented at WKNEPHTV (ICES, 2007).

In 2007, poor visibility hampered the survey and despite repeated attempts at over 15 stations, turbidity scores precluded the use of some of the counts. Following reanalysis in 2010, these data were considered too unreliable and no abundance estimates were derived for this year.

The algorithm used to determine the distance towed on each station, changed in the WG of 2011. GPS measurements are recorded at one second intervals during each tow. Prior to 2011 the distance towed was determined by summing up the distance travelled between each positional record. As the GPS transceiver is mounted high up on the research vessel, the positional data generated will be influenced by the sea state far more than the sledge. Close examination of the GPS points showed that rolling of the vessel was recorded and this motion is not transmitted to the sledge. In order to reduce the influence of ship motion on the sledge distance, a smooth spline model of position was fitted to each tow with sufficient flexibility to capture large, slow movements whilst capable of smoothing through the short frequency movement cause by wave action. The previous practice of determining distance travelled by summing up the distance between each recorded "ping" appears to have significantly over-estimate the distance travelled (typically +30%) which translated into a reduced density of burrows.

In 2012, there was an historical revision of burrow density estimates from the TV survey (2008–2011 series) using a more accurate field of view (0.75 m) and a bias of 1.2. The new estimates show a decrease of around 10% in abundance compared with last year's estimations for the dataseries.

In 2015, a new revision was done to FU14 *Nephrops* grounds based on new available data: VMS, UWTV data and sediment information (ICES, IBPNeph 2015). The approach accepted in the IBP process for the main ground was based on co-kriging (VMS main variable; and *Nephrops* densities and sediment distribution secondary variables). For Wigtown Bay a more simplistic method based on the Fit to VMS was used, as data available for sediment distribution and *Nephrops* densities were not enough to run other models. The redefinition of the main polygon resulted in a 6% decrease for the main area, from 1032.75 Km^2 to 1019.79 Km^2, although in total due to the increase of Wigtown Bay the total FU14 fishing area is still very similar, from 1052.37 Km^2 to 1087.01 Km^2.

Ground	Area Km^2	Source
Main ground	1019.79	ICES, IBPNeph 2015
Wigtown Bay	67.21	ICES, IBPNeph 2015
Wigtown Bay in relation to Main ground = 6.6% *		

*** For now the total abundance estimate is still based on extrapolation to include this additional ground but more work in Wigtown Bay is needed as it became a more significant fishing patch. This should be explored in future benchmark work.**

These new revised areas are considered to be better shaped to the current fishing activity and *Nephrops* distribution although subject to refinement when additional data become available, i.e. positional information for <12 meter vessels, sediment distribution and *Nephrops* densities estimates for Wigtown Bay (including more UWTV stations).

	Original abundance			IBPNeph 2015 estimations			
	without Wigtown	Final abundance (Including Wigtown 1.9%)	Mean Krigged density (no./m^2)	without Wigtown	Final abundance (Including Wigtown 6.6%)	Mean Krigged density (no./m^2)	% change in relation to original abundance
2011	423.0	431.0	0.41	421.4	449.2	0.41	4.2
2012	640.5	652.7	0.62	650.8	693.8	0.64	6.3
2013	457.0	465.7	0.44	456.9	487.0	0.45	4.6
2014	424.4	432.5	0.39	421.3	449.1	0.41	3.8
2015				554.0	590.5	0.54	

Since 2011, the procedure to estimate *Nephrops* abundance uses a geostatistical approach and runs using R statistical package with the gstat, maptools, and spatstat libraries. The former approach used calculated the mean density of non-zero counts which was raised to the total fished area. This approach ignored the spatial distribution of the counts and was highly sensitive to the total area used for raising. The geostatistical procedure takes the spatial position of the burrow density estimates and fits a semi-variogram model to describe the how variance changes with distance. The process is described below.

A boundary file 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) 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, locations=~lon.m+lat.m, data=recounts7)

vario.recount <- variogram(BurrowDensity~1 , locations=~lon.m+lat.m, data=recounts7)

fit.vario.recount <- fit.variogram(vario.recount, model=vgm(0.1, "Exp", 15 000, 0.03))

plot(vario.recount, fit.vario.recount)
```

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, boundary$dist.lon, boundary$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*250 000)/1 000 000) /bias# each cell represents a 500 m*500 m block = 250 000 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 ~10% 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 (Table 1).

Table 1. Absolute abundance conversion factors.

Time period	Edge effect	Detection rate	Species identification	Occupancy	Cumulative Absolute Conversion Factor
<=2012	1.3	0.75	1.15	1	1.2

Edge effect: Same sledge and set up as Western Irish Sea. Larger burrows systems increase the edge effect.

Detection rate: Same sledge and set up as Western Irish Sea and same staff so detection rate maintained.

Species identification: Factor kept the same as Wastern Irish Sea; less *Calocaris* spp but *Goneplax* spp. are prevalent across the ground.

B.4. Commercial cpue

Lpue/cpue series are no longer required to be presented at WGCSE reports, thus no further investigations were done regarding effort and lpue series for this stock.

B.5. Other relevant data

Summary of assessment parameters presented in the following text table:

Parameter	Value	Source
Length Distributions		two year average length–frequency distributions reference period 2013–2014.
Discard Survival	10%	WGCSE 2015
TV selectivity	17 cm	
MALES		
Growth - K	0.160	Irish Sea West data ; Bailey and Chapman (1983)
Growth - L(inf)	60	"
Natural mortality - M	0.3	Brander and Bennett (1986; 1989)
Length/weight - a	0.00022	Hossein *et al*. (1987)
Length/weight - b	3.348	"
FEMALES		
Immature Growth		
Growth - K	0.160	Irish Sea West data ; Bailey and Chapman (1983)
Growth - L(inf)	60	"
Natural mortality - M	0.3	Brander and Bennett (1986; 1989)
Size at maturity	24	Briggs (1988)
Mature Growth		
Growth - K	0.100	Irish Sea West data ; Bailey and Chapman (1983)
Growth - L(inf)	56	"
Natural mortality - M	0.2	Brander and Bennett (1986; 1989)
Length/weight - a	0.00114	Hossein *et al*. (1987)
Length/weight - b	2.820	"

C. Historical stock development

1) Survey indices are worked up annually resulting in the TV index.
2) Adjust index for bias (see Section B3, Table 1). 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 the average of the three most recent years. If, however, there is strong evidence of a recent trend then apply most recent value (don't attempt to extrapolate the trend further in the future).

D. Short-term projection

1) The catch option table will include the harvest ratios associated with fishing at $F_{0.1}$, $F_{35\%SpR}$ and F_{max} (Table 2). These values have been estimated by the Inter-Benchmark Workshop (ICES, IBPNeph 2015) and are to be revisited by subsequent benchmark groups if there indications of changes to fishery or biological factors. The values are FU specific and have been put in the stock annexes.
2) 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.
3) Multiply the survey index by the harvest ratios to give the number of total removals.
4) Create a landings number by applying a discard factor.
5) Produce landings biomass by applying mean weight.

Under a landing obligation scenario the suggested catch option table format is as follows (example for Advice October 2015).

Landing Obligation applies				
	Harvest ratio	Catch	Wanted catch	Unwanted catch
Fsq_2013–2014	6.7%	780	**734**	46
Fcurrent	7.5%	865	**814**	51
F0.1Male	10.0%	1156	**1088**	68
F0.1Comb	11.0%	1272	**1197**	75
F0.1Female	12.0%	1387	**1305**	82
F35%Male	12.0%	1387	**1305**	82
F35%Comb	13.0%	1503	**1414**	89
F35%Female	15.0%	1734	**1632**	102
FMAXMale	16.0%	1849	**1740**	109
FMAXComb	18.0%	2081	**1958**	123
FMAXFemale	22.0%	2543	**2393**	150

E. Medium-term projections

F. Long-term projections

G. Biological reference points

Under the ICES MSY framework, exploitation rates which are likely to generate high long-term yield (and low probability of overfishing) have been evaluated and proposed for each *Nephrops* functional unit. Owing to the way *Nephrops* are assessed, it is not possible to estimate F_{MSY} directly and hence proxies for F_{MSY} have been determined. Three stock-specific candidates for F_{MSY} ($F_{0.1}$, $F_{35\%SPR}$, and F_{MAX}) were derived from a length-based per recruit analysis (these may be modified following further data exploration and analysis).

New MSY explorations were carried out at IBPNeph 2015 for FU14.

Density of *Nephrops* in FU14 is considered moderate (~0.49 burrow/m^2, average 2011–2015) and the exploitation rate is currently even for both sexes. It is expected that a combined sex $F_{0.1}$ is a suitable F_{MSY} proxy for this stock. This corresponds to a harvest rate of 11% and this value is expected to deliver high long-term yield with a low probability of recruitment overfishing. These calculations assume that the UWTV survey has knife-edge selectivity at 17 mm and that the supplied length frequencies represented the population in equilibrium. This more conservative option is also based in the fact that some biological parameters are poorly known.

Table 2. LCA model outputs calculated at IBPNeph 2015. These are used in the catch option table.

Calculated at IBPNeph 2015 – F_{MSY} = 11.0% ($F_{0.1}$ combined)						
		F_{BAR} 20–40 mm		Harvest Rate	Virgin spawner per recruit	
		Female	Male		Female	Male
F0.1	Comb	0.18	0.17	11.0%	46%	41%
F0.1	Female	0.21	0.2	12.0%	42%	37%
F0.1	Male	0.17	0.16	10.0%	48%	43%
F35	Comb	0.24	0.23	13.0%	39%	33%
F35%	Female	0.29	0.28	15.0%	35%	28%
F35%	Male	0.22	0.21	12.0%	41%	35%
Fmax	Comb	0.38	0.36	18.0%	30%	23%
Fmax	Female	0.54	0.52	22.0%	23%	16%
Fmax	Male	0.32	0.31	16.0%	33%	26%

Additionally an $MSYB_{trigger}$ has been developed for FU14 at IBPNeph 2015, based on the lowest observed UWTV abundance time-series (corresponds to the abundance observed in 2009).

	Type	Value	Technical basis
MSY	MSY $B_{trigger}$	350 million	Defined as the lowest stock size from which the abundance has increased, correspondes to the abundance observed in 2009 (IBPNeph 2015).
Approach	F_{MSY}	11% harvest ratio	Equivalent to $F_{0.1}$ for combined sexes (IBPNeph 2015).

No further reference points were identified, although further on a MSY B_{buffer} might need to be calculated for this stock, depending on the outcomes of WKMSYRef4 (13–16 October 2015).

H. Other issues

H.1. Historical overview of previous assessment methods

Not relevant for this stock.

I. References

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