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Report of the Inter-Benchmark Protocol of *Nephrops* in FU 17 and 14 (IBPNeph)

June-September 2015

By correspondence

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1 Executive Summary

This was the first benchmark exercise for the East Irish Sea *Nephrops* stock - FU 14.

There were three main areas requiring investigation as part of the inter-benchmark process for FU14 *Nephrops*:

- Revisions to the area of the *Nephrops* grounds based on new available data: VMS, UWTV data and sediment information;
- A review of fishery data and raising procedures;
- Review of Reference points: F_{MSY} proxies and MSY $B_{trigger}$

Three different approaches were tested to redefine the current fishing area in the main ground: Fit to VMS data (based on VMS data); Weighted overlay (parameters weights: based 60% VMS, 30% *Nephrops* densities and 10% sediment distribution); Co-kriging (VMS is the main variable; and *Nephrops* densities and sediment distribution are secondary variables). 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.

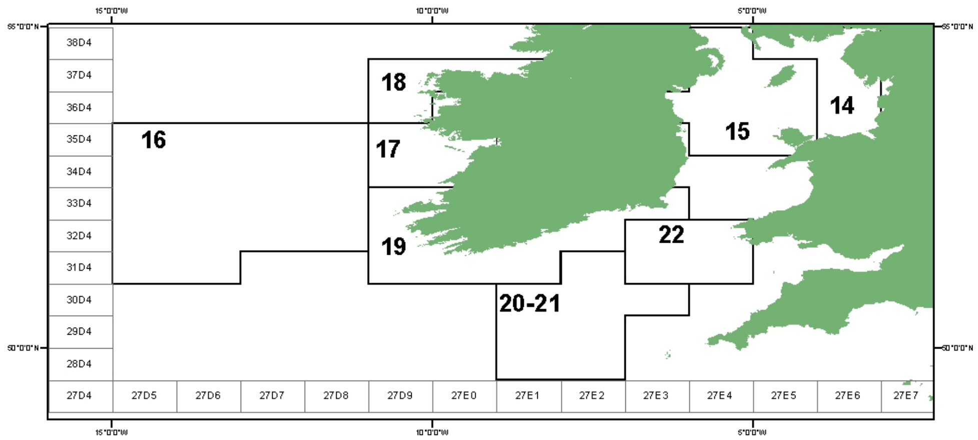
There were identified three sampling programme that collected biological information for *Nephrops* in the East Irish Sea: *Nephrops* catch sampling (catch component–1999 to current); Observer programme (retain and discard component–2003 to current); Market sampling (landings component–1983 to current). 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 it is 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%.

New MSY explorations were carried out at the current IBP for FU14. A SCA (separable cohort analysis, model Bell) was used to estimate sustainable stock-specific Harvest Ratio reference points. $F_{0.1}$ is still suitable as F_{MSY} proxy for this stock, which now corresponds to a harvest rate of 11%. $B_{trigger}$ was identified for the first time for this stock, which is now set at 350 million (abundance observed in 2009).

2 Introduction

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

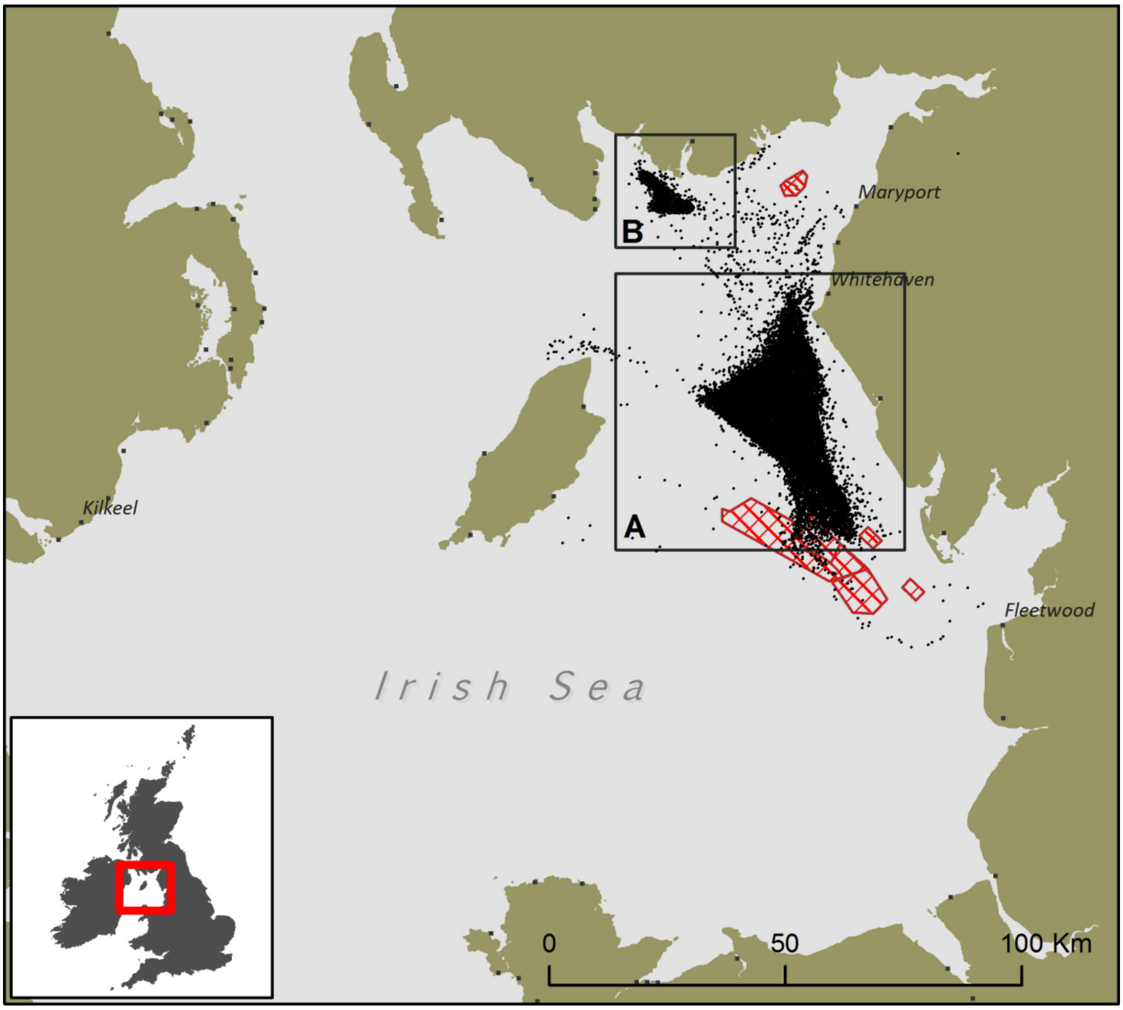
Nephrops Functional Units in Subarea VII: Irish Sea West (FU15) stock; the Porcupine Bank (FU16); Aran Grounds (FU17); northwest Irish Coast (FU18), southeast and southwest Irish Coast (FU19); and the Labadie, Jones and Cockburn bank (FU20–21) and Smalls Ground (FU22).



FU14 ICES rectangles: 38E5, 38E6, 37E6, 36E6, 35E5.

The Eastern Irish Sea *Nephrops* fishery is an UK lead fishery, representing on average 94% of the reported annual international landings (2005–2014) and is considered to be a relative small fishery within Area VIIa where landings fluctuated over the past ten years within 495–959 tonnes (Table 1.1). The main fleets targeting *Nephrops* include directed single-rig and twin-rig otter trawlers operating out of ports in UK (NI), UK (E&W) and Republic of Ireland (around 50 UK active vessels, Figure 1.1).

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.

The main fishing ground as been annually surveyed by UWTV since 2007, although Wigtown Bay has been only covered in few years due to bad weather and/or poor visibility conditions (coastal and shallow with influx of freshwater which usually affects the visibility). In 2008 it was estimated the Wigtown Bay area was 1.9% of the area of the main patch, so the survey abundance number has been simply inflated by that proportion.

This stock is classified as *category 1* as it has a regular annual UWTV survey, although the collection of biological sampling data for this area has been testing and there are few years of poor sampling along the time-series. The lack of good sampling was more notorious between 2010 and 2012. In 2013 and 2014 sampling there was good sampling coverage of this area and this allows a full revision of the current stock status and update of reference points. This inter-benchmark is addressing a revision of mean sizes, mean weight, sex ratio and a revision of the reference points based on the recent sampling data. Additionally the impact of the construction of Walney (UK) Offshore Windfarms Ltd. was also analysed during this benchmark process. The wind farm has impacted fishing behaviour and has created effort displacement to other areas. Revisions of the fishing grounds will imply modifications to the total area used in the geo-statistical model to estimate the total *Nephrops* abundance.

The 2015 Inter-Benchmark Protocol of *Nephrops* in FU 14 and FU 17 has the following general objectives:

a) Revise the area of the *Nephrops* grounds used for the stock based on recent multibeam, VMS and UWTV data.

b) Review current stock parameters (i.e. L/W, growth, maturity, M, discard survival), fishery data and raising procedures and revise if appropriate.

c) Re-examine and update (if necessary) F_{MSY} proxies and MSY $B_{trigger}$ for *Nephrops* in FU 14 and FU 17.

d) Describe the resulting data analysis procedure and assessment methodology in the stock annexes.

e) Review and agree on the resulting stock annexes.

3 Review of *Nephrops* ground area in FU14

Between 2010 and 2012 fishing was restricted in the south part of the main ground due to the construction of the Walney offshore wind farm. 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 wind farm area.

Nowadays fishing is allowed in the overall wind farm area (there is only an exclusion zone around each wind turbine) although there is evidence of very low usage of the south part of the main ground by vessels over 12 meters, nevertheless shifts in the fishing pattern of smaller vessels is unknown as there is no positional information available for under 12 meter vessels. Figure 3.1 shows the distributions of fishing activity for FU14 since 2006 and it is visible that since the construction of the wind farm there has been some effort displacement into Wigtown Bay and the overall fishing area changed in the main ground.

Three different approaches were tested to redefine the current fishing area in the main ground:

- Fit to VMS data (based on VMS data);
- Weighted overlay (parameters weights: based 60% VMS, 30% *Nephrops* densities and 10% sediment distribution);
- Co-kriging (VMS is the main variable; and *Nephrops* densities and sediment distribution are secondary variables).

For Wigtown Bay, due to data limitations on *Nephrops* densities and sediment distribution, the area was revised by using the Fit to VMS approach, which is only based on VMS data.

Data used to support this analysis are given in the text table below and data layers are represented in Figure 3.2.

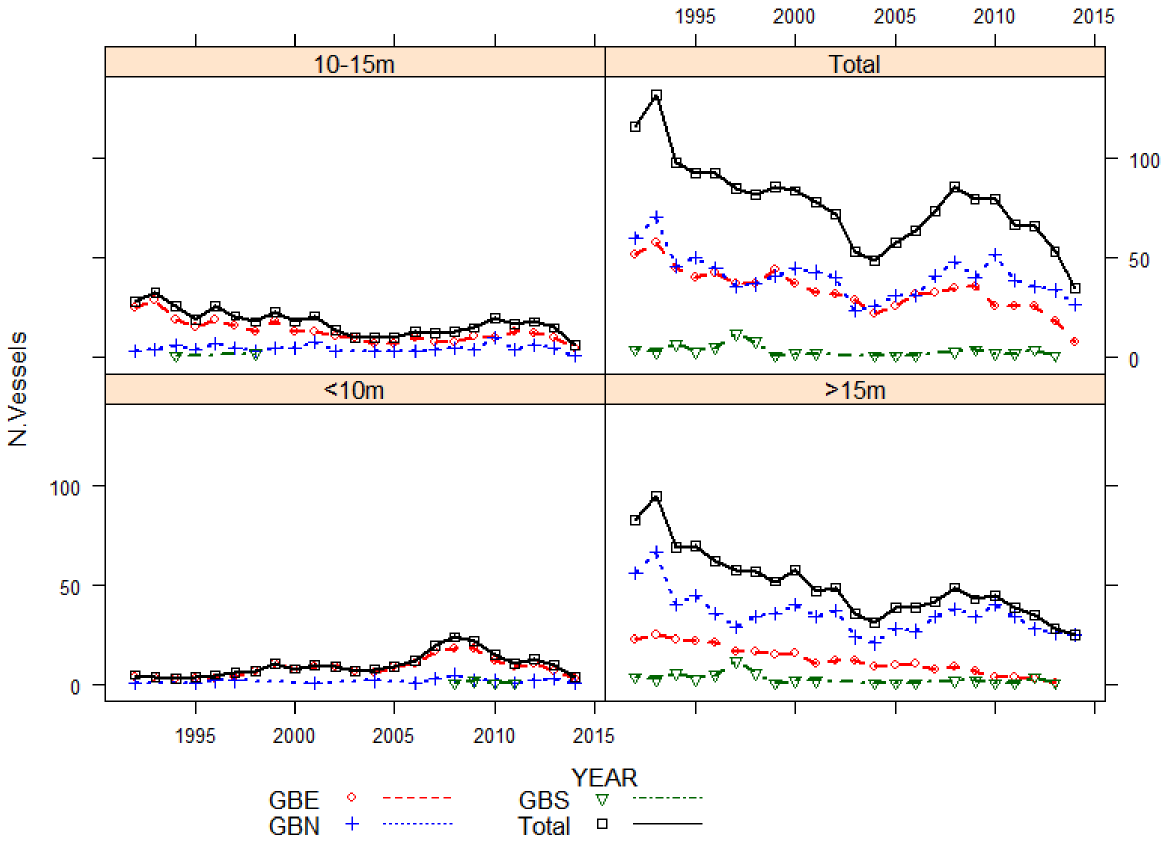


Figure 1.1. Irish Sea East (FU14): UK active vessels, showing the split by <10 m, 10–15 m, >15 m vessels and total for UK vessels.

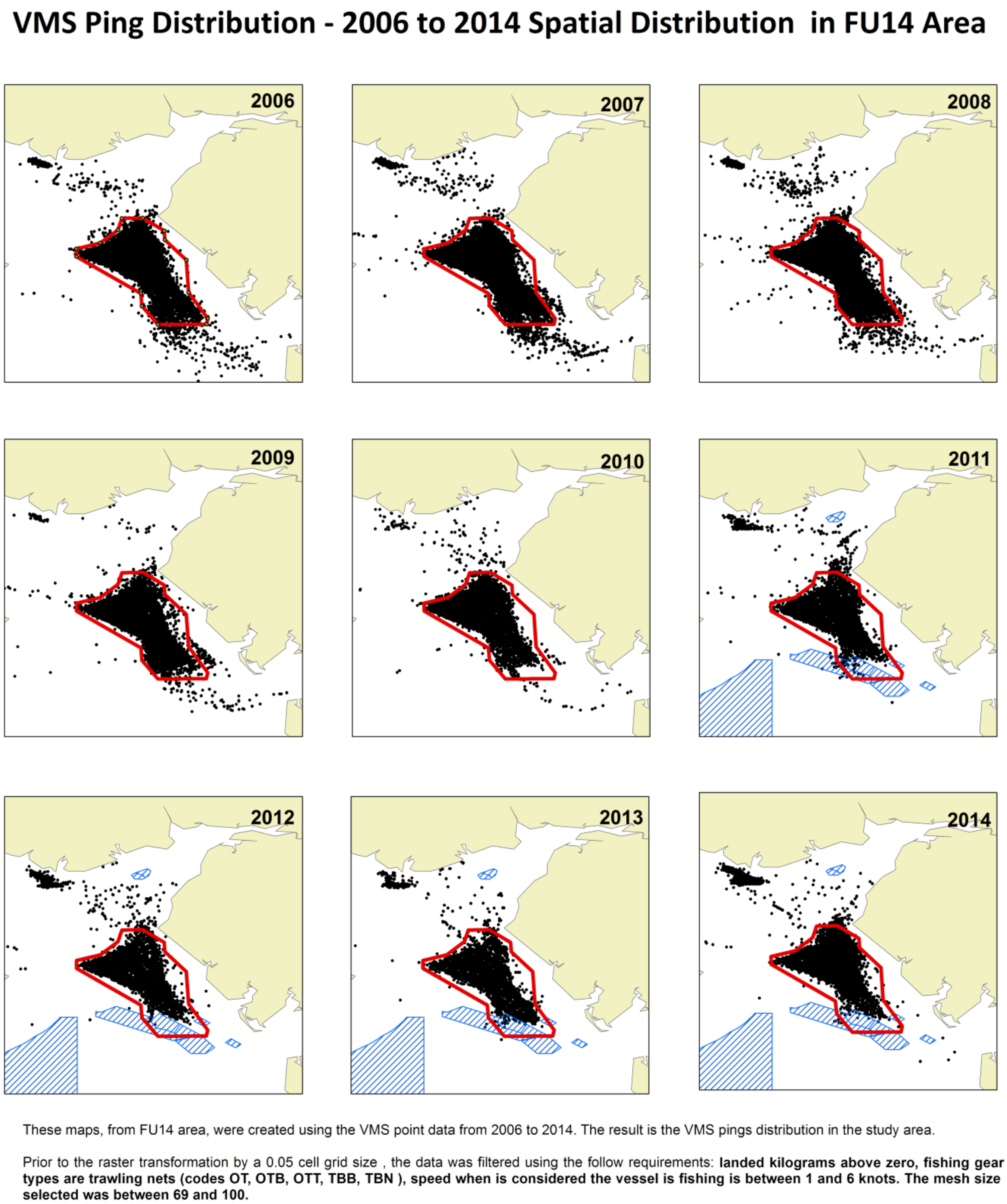


Figure 3.1. Irish Sea East (FU14): VMS fishing activity. From 2013 it includes vessels over 12 meters.

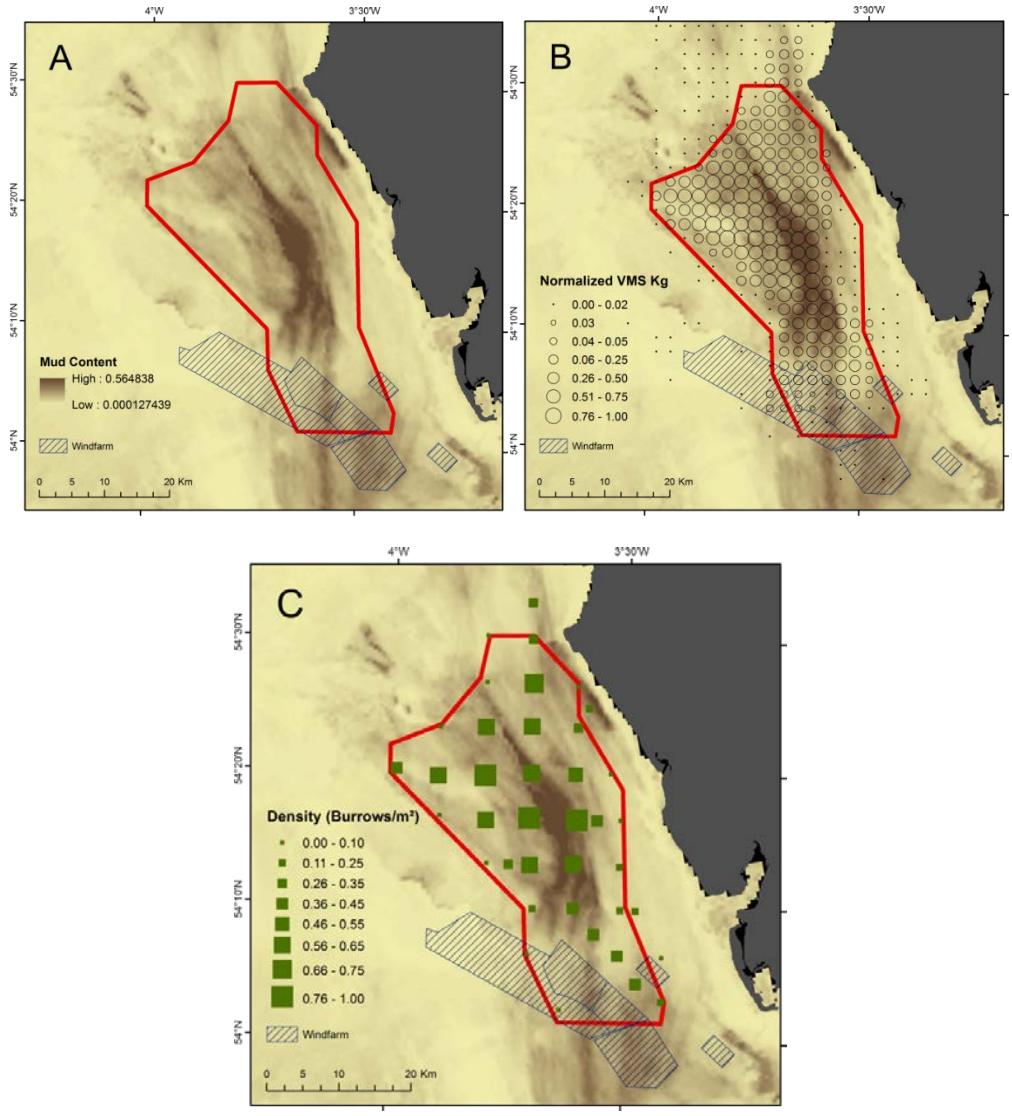


Figure 3.2. Irish Sea East (FU14): Data layers used in the analysis. A. Mud represented in a scale from 0 to 1. B. VMS, where each cell represents the sum of the kilograms of the VMS points that are within the 0.025 degrees cell size. C. Abundance represented in a density scale from 0 to 1 burrowns per m^2. The original assessment polygon is represented in red and the wind farm areas are identified here as blue coloured polygons.

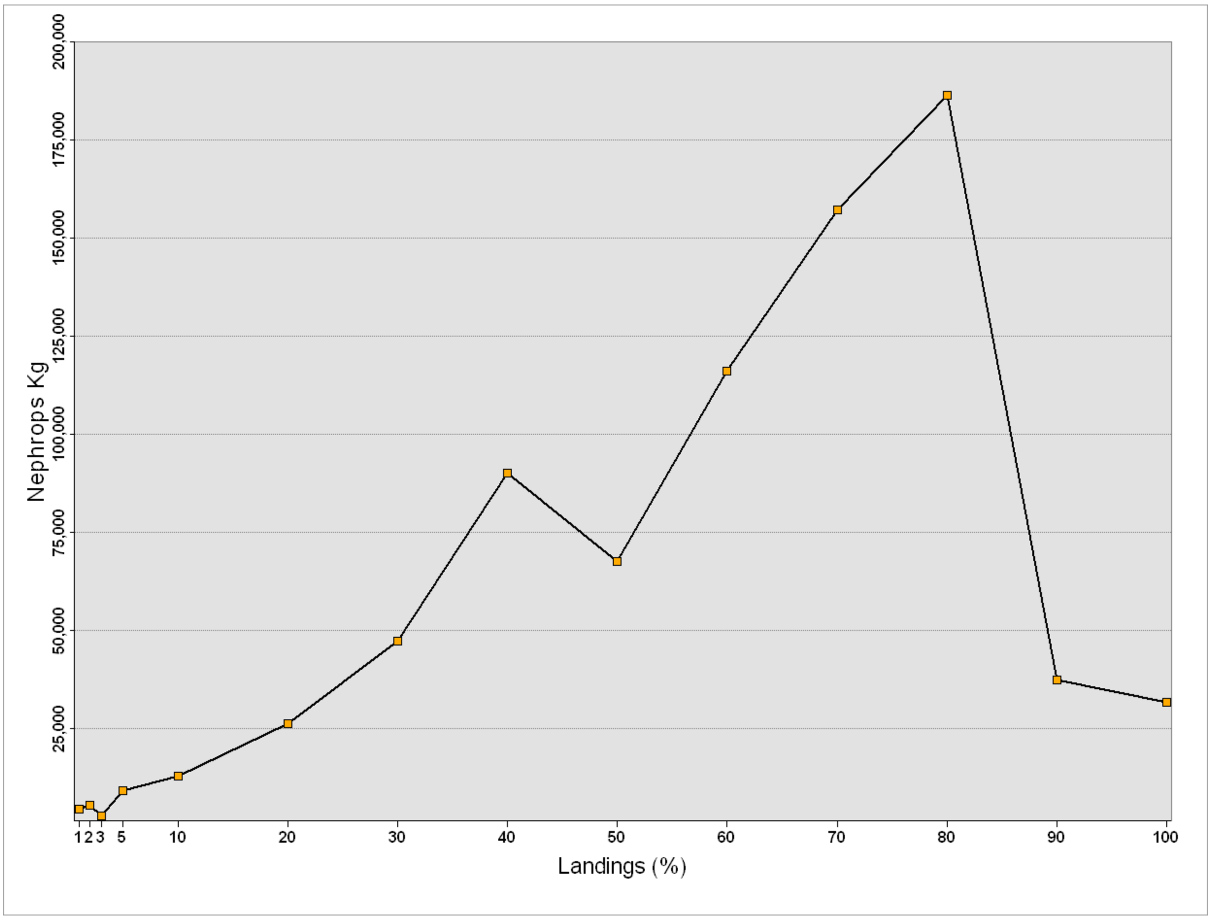


Figure 3.3. Irish Sea East (FU14): Sum of *Nephrops* landing kilograms within landings percentiles.

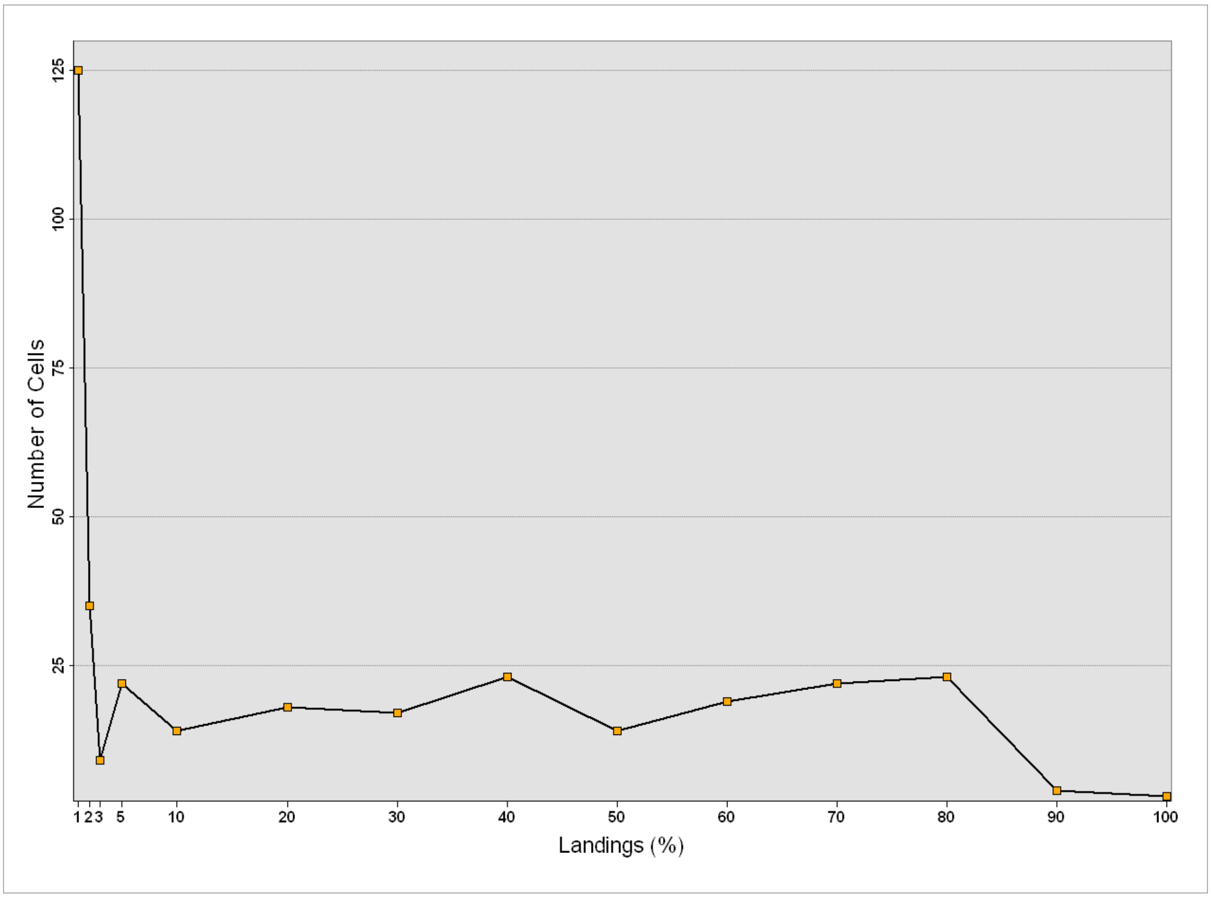


Figure 3.4. Irish Sea East (FU14): Sum of cells within landings percentiles.

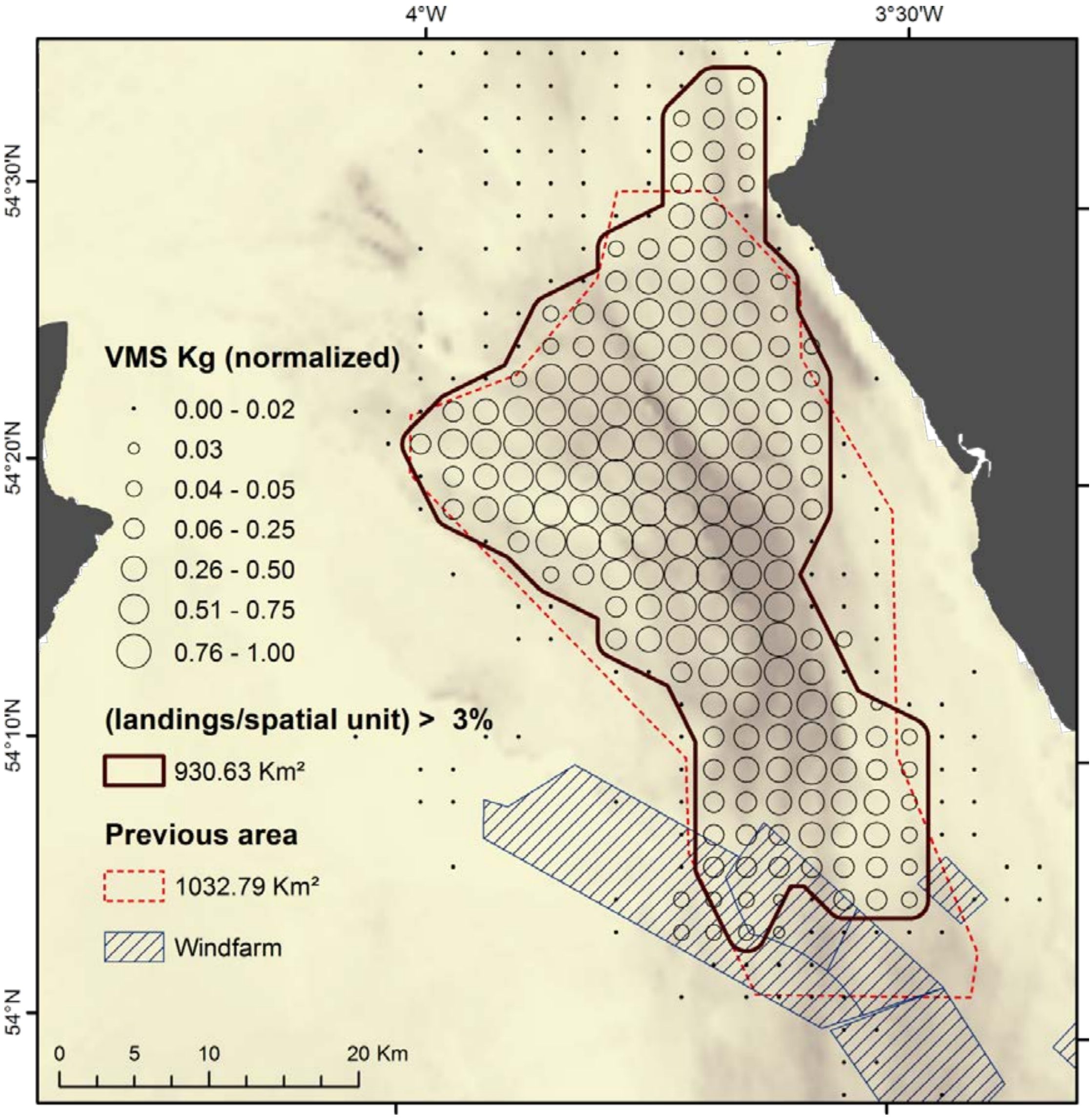


Figure 3.5. Irish Sea East (FU14): Fit to VMS approach with a cut off of 3% of the maximum Kg landed per spatial unit (0.025 degrees cell); this represents the area where *Nephrops* landings (aggregated 2010–2014) are higher than 3% per spatial unit.

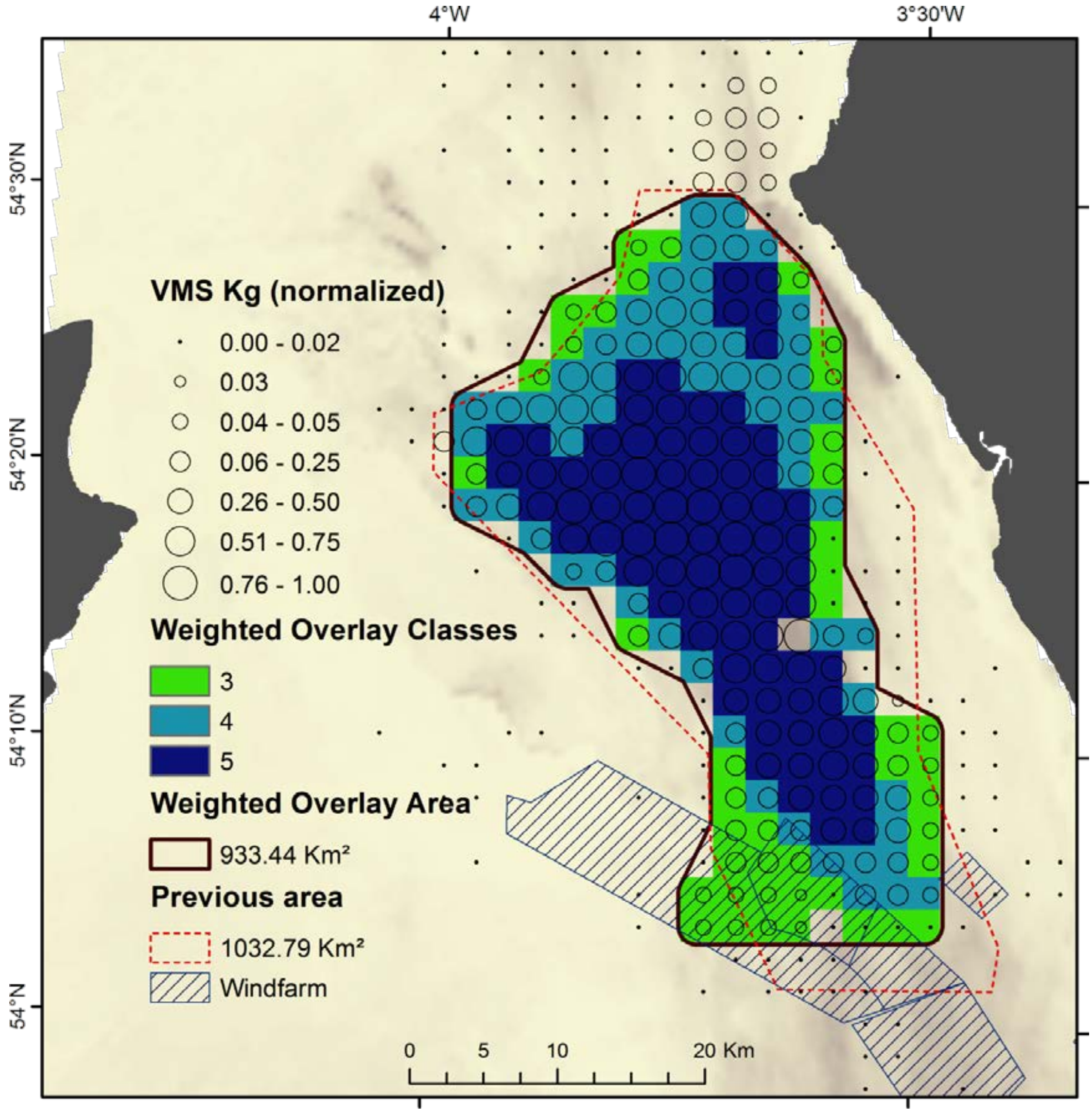


Figure 3.6. Irish Sea East (FU14): Weight overlay approach, using as input values 60% for VMS, 30% for *Nephrops* densities from the UWTV survey and 10% for the sediment prediction model.

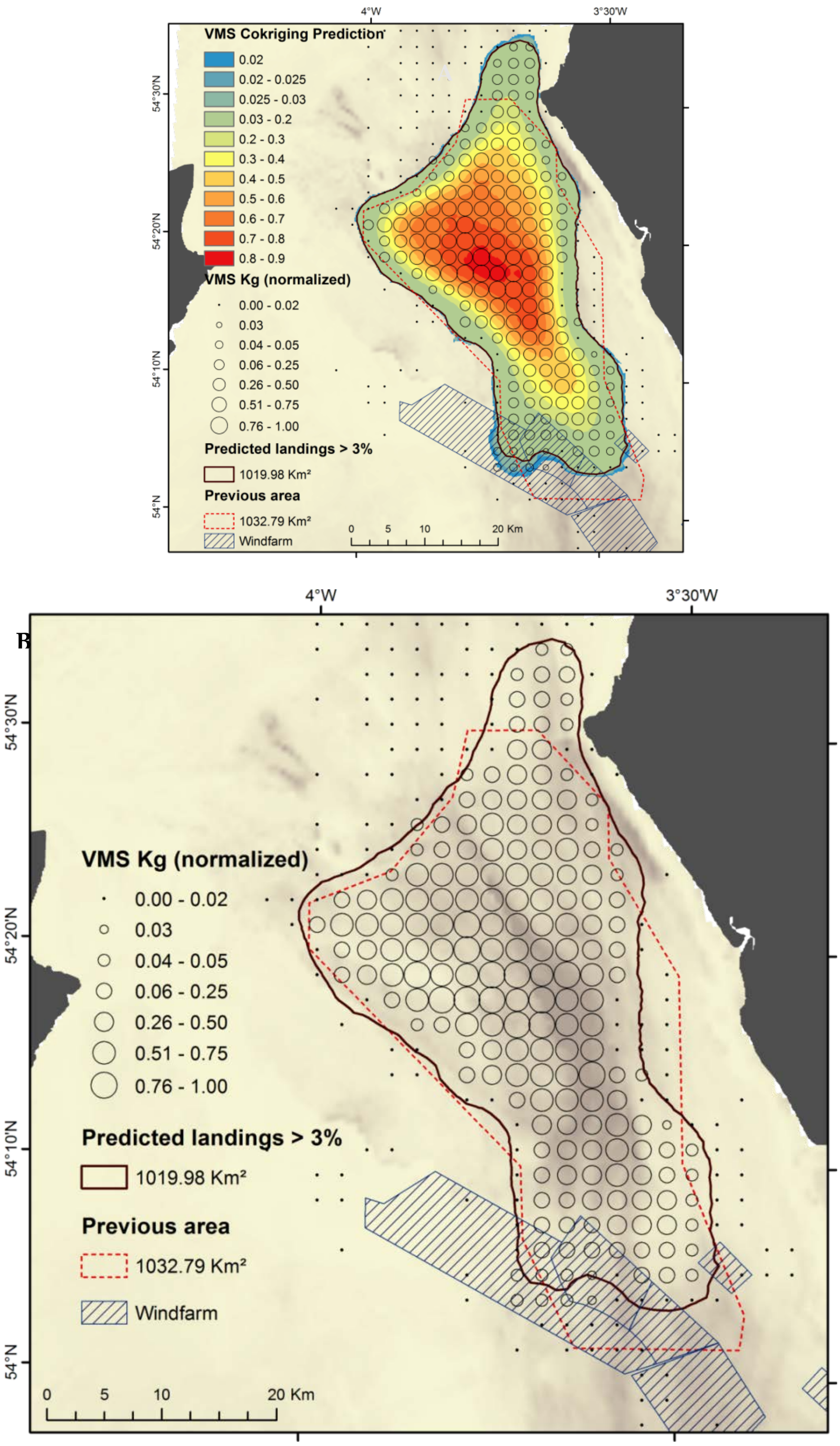


Figure 3.7. Irish Sea East (FU14): Co-kriging approach. Interpolation result of VMS (cut off 3%), survey density (2013–2015) data and mud distribution. A – model output; B – final polygon.

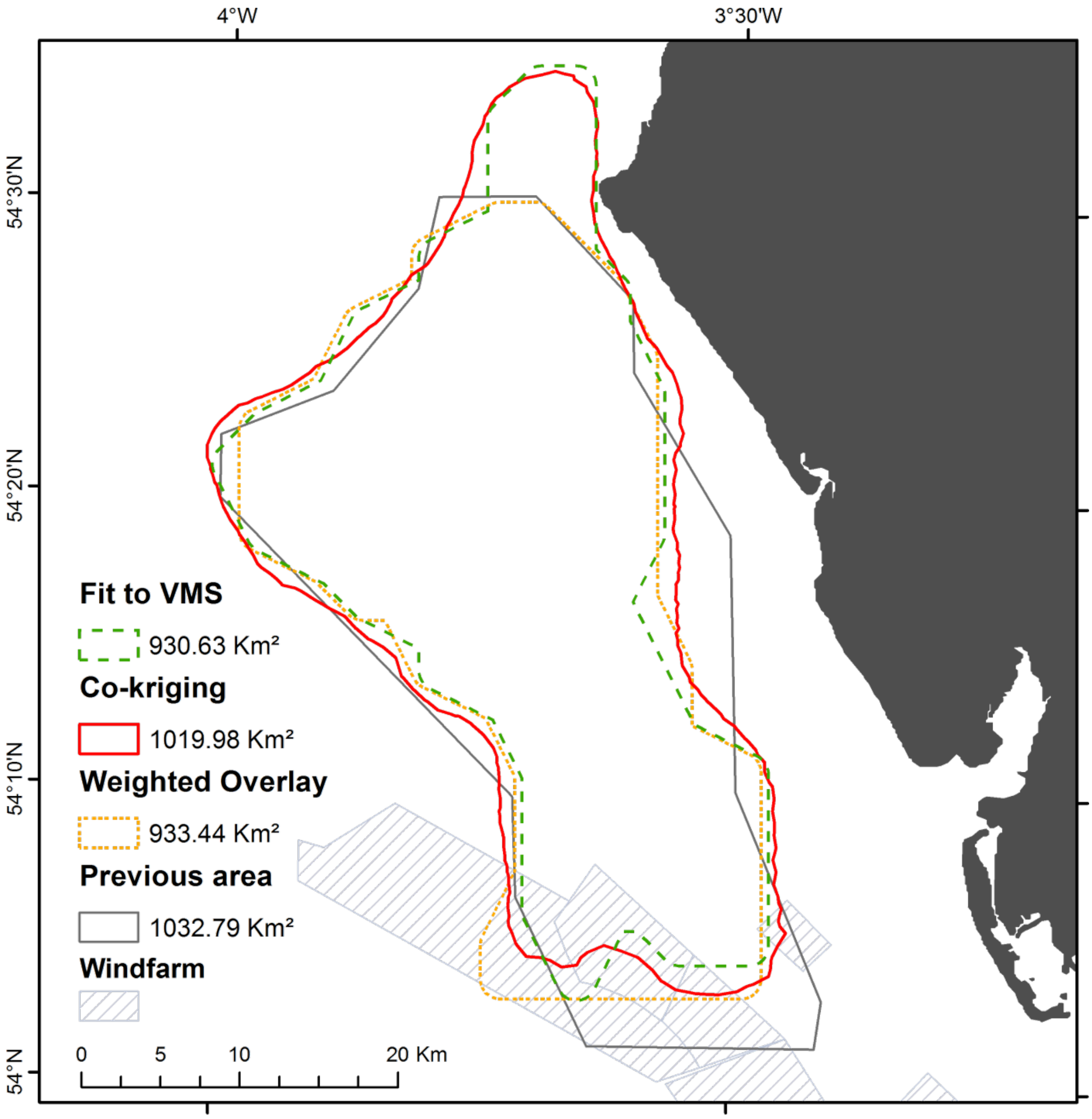


Figure 3.8. Irish Sea East (FU14): Comparison of all test polygons: Fit to VMS in green, Co-kriging in red, Weighted overlay in orange and original polygon in grey.

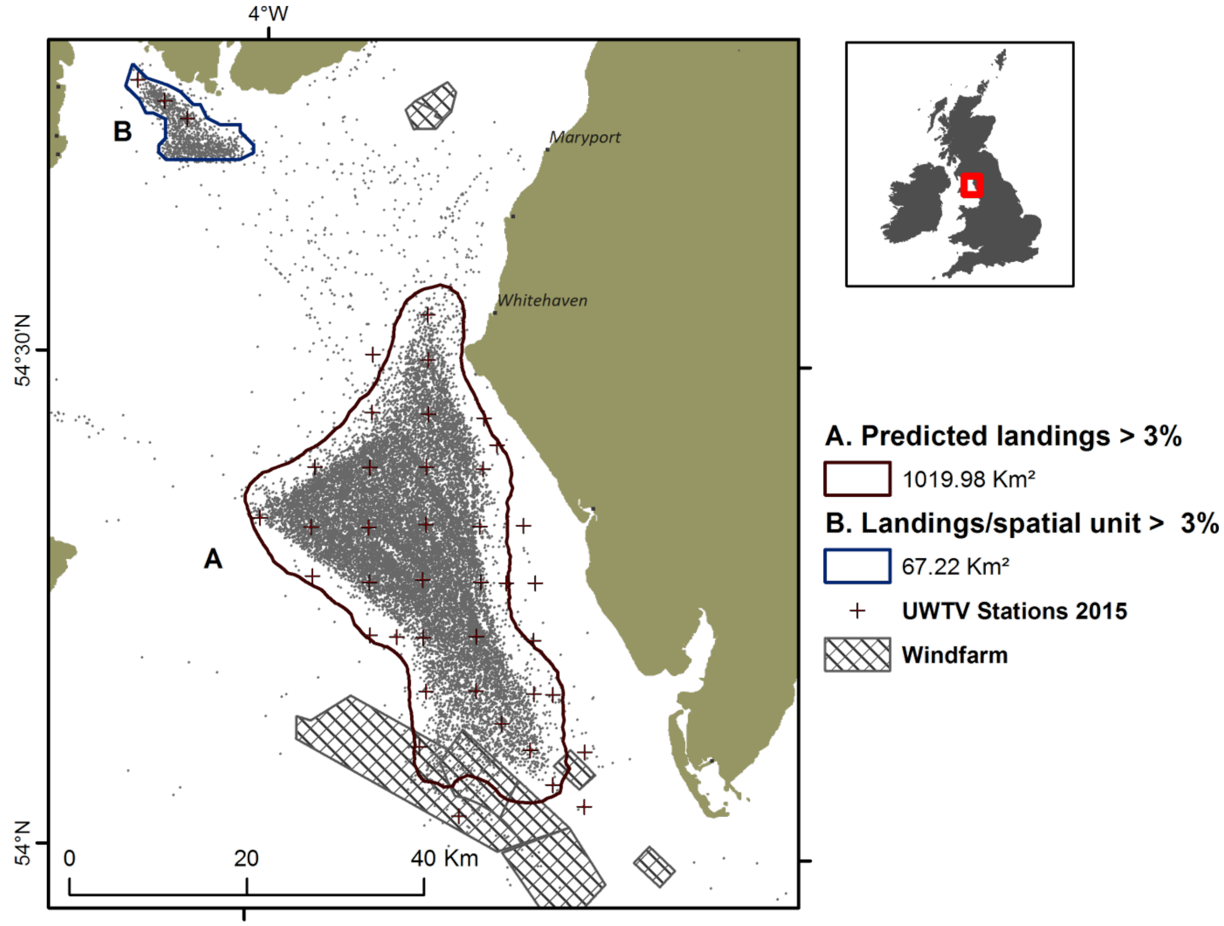
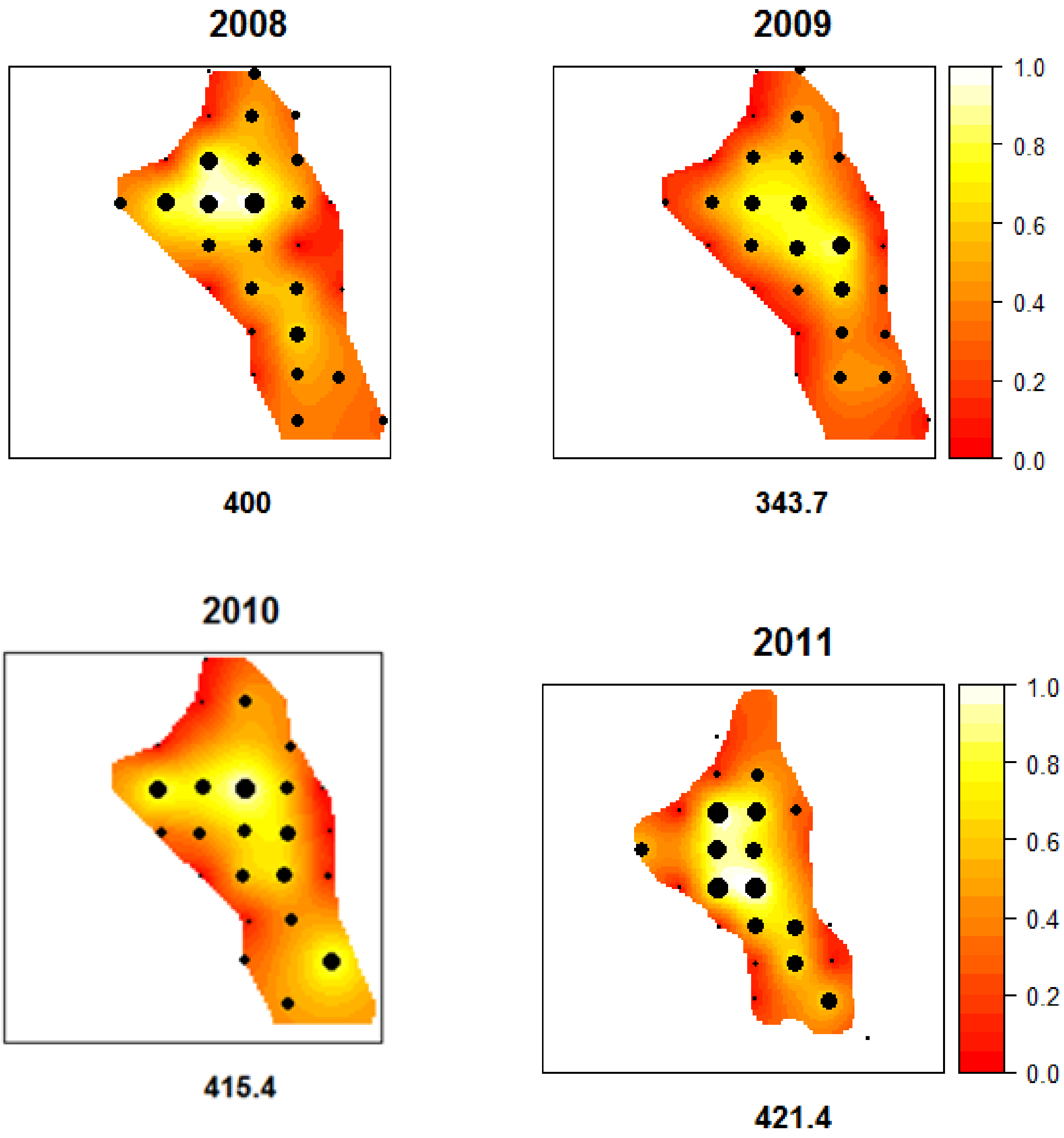


Figure 3.9. Irish Sea East (FU14): Final estimated areas for both grounds based on the co-kriging approach for the main ground (1019.79 Km^2) and on the Fit to VMS approach to Wigtown Bay (67.22 Km^2). VMS distribution is displayed without any restriction.


2008
400
2009
343.7
1.0
0.8
0.6
0.4
0.2
0.0
2010
415.4
2011
421.4
1.0
0.8
0.6
0.4
0.2
0.0

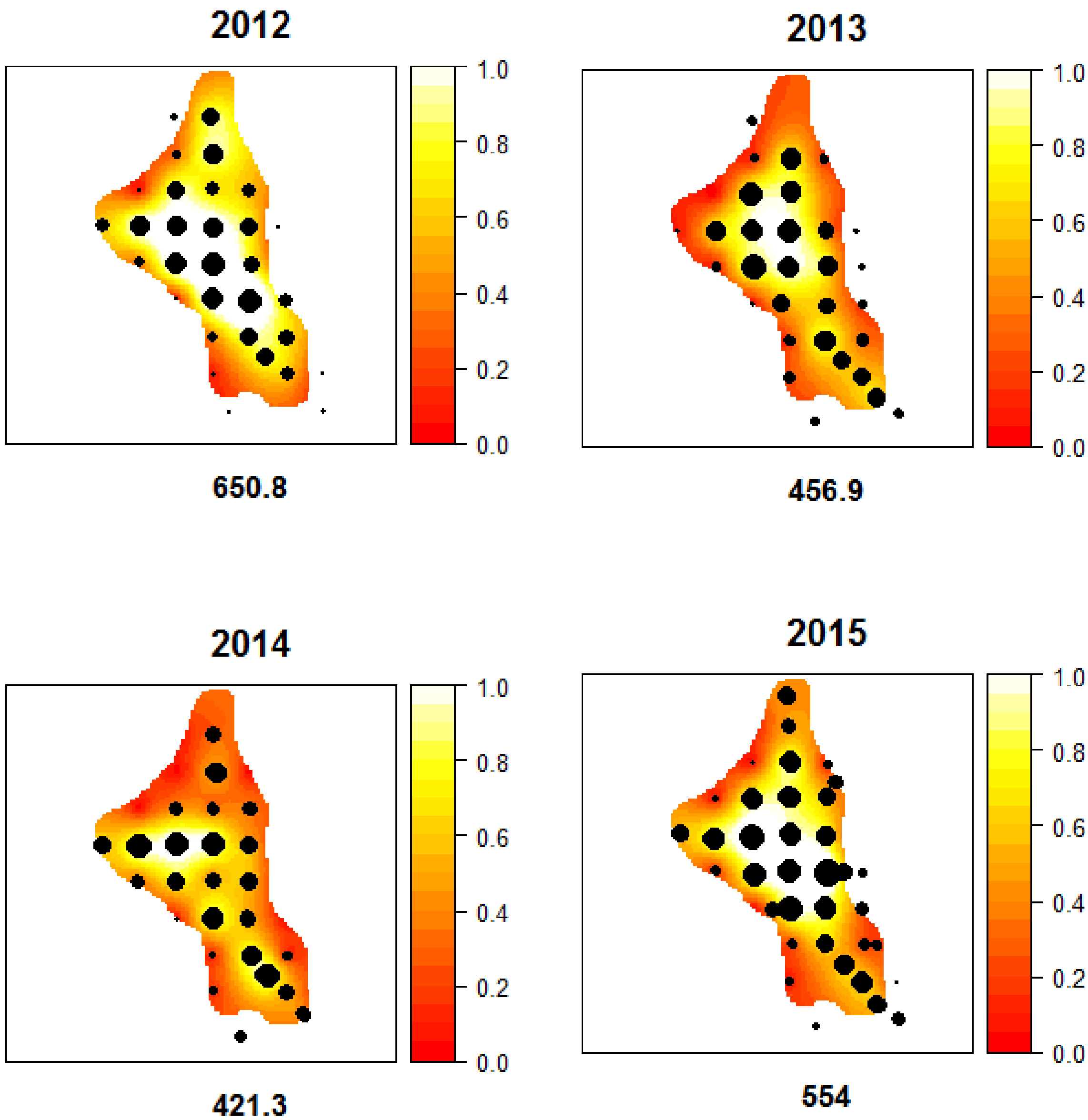


Figure 3.10. Irish Sea East (FU14): Burrow density estimates from the UWTV Survey 2008–2015. Abundance estimates given at the bottom of each plot are adjusted with the cumulative absolute conversion factor (but does not contain the additional area for Wigtown Bay). Area of ground = 1032.75 Km² 2008–2010 and 1019.79 Km² for 2011–2015.

	SOURCE	DESCRIPTION
VMS data	VMS / FAD landings database	Vessel Monitoring Systems data 2010–2014, with a ping interval average of two hours. The VMS data are linked to the *Nephrops* landings by voyage and vessel ID. The total landings reported per ICES voyage id are distributed across the fishing 'pings' for that ICES voyage id. Data filtered by: *Nephrops* Kg landed above zero, fishing gears – OT, OTB, OTT, TBB and TBN, speed between 1 and 6 knots and mesh size between 69 and 100 mm. Speed selection criteria was based on the results of Lee *et al*., 2010, which concluded that the use of a 1–6-knot speed filter could provide an effective means of distinguishing most of the fishing activity for all gears. VMS data were aggregated using a 0.025 degrees cell size for the main ground and 0.010 for Wigtown Bay, where each cell represents the sum of the kilograms of the VMS points that are within the cell. These cells sizes represent the lowest possible resolution, below these sizes there where cells with no data.
UWTV survey data	Annual UWTV surveys	*Nephrops* densities per survey station, 2013 and 2015 data. The *Nephrops* density is represented in a scale from 0 to 1.
Sediment data	Extracted from the Pangae site (http://doi.pangaea.de/10.1594/PANGAEA.845468). The dataset citation : Stephens, David (2015): North Sea and UK shelf substrate composition predictions, with links to GeoTIFFs. Centre for Environment, Fisheries and Aquaculture Science, doi:10.1594/PANGAEA.845468.	A random forest regression model is used to predict percent mud/sand/gravel content for the North Sea and UK shelf. Predictions are made using outputs from hydrodynamic models as well as optical remote sensing data from satellite platforms and bathymetric variables, which are mainly derived from acoustic remote sensing. GeoTIFFs with a 500 m resolution of mud/sand/gravel fractions are given as well as substrate classes (EUNIS and Folk).

Fit to VMS data

Input values

Variables	Description
VMS	VMS aggregated 2010–2014

Description: The VMS points are linked to the landed kg per point.

Method to create polygon: *Nephrops* landing data were joined to VMS points by voyage, vessel ID and assigned to each point based in the ping time interval. A raster grid with 0.025 degrees cell size was created (representing the smallest possible grid size where all cells have points), in order to sum the VMS within each cell, using the *Nephrops* kilograms landed attribute. The result dataset has a minimum of 3 kg and maximum of 9200 kg.

The summed data correspond to 2010–2014 time period, since 2010 is the year when the wind park construction starts. Therefore the data were normalized by year (dividing the total kg for each cell by 5, number of years) and normalized by minimum–maximum method in order to scale the data from 0 to 1. With this scale, boundaries limits can be created were a certain percentage of *Nephrops* kg occurs, this procedure excludes residual VMS points and helps defining the fishing area.

The broad definition of fishing activity based upon vessel speed (1–6 knots) can create anomalous points in which very rare cases of "fishing activity" are defined significantly beyond the main ground. Routines fitting the ground definition around these points will look to include such outliers, however they are more likely to represent a misclassification of fishing when steaming to another ground or port. In order to reduce the influence of such outliers, different boundaries were created using several cut offs based on the maximum value of *Nephrops* Kg landed. The *Nephrops* kilograms per cells were reclassified by percent of the maximum of kilograms landed (Figure 3.3). In this figure it is visible that the 1%, 2% and 3% represent the minimum amount of *Nephrops* kg while after 5% kilograms increase significantly. Figure 3.4 represents the number of cells within each of the percent classes and reproduces the same trend than the Figure 3.3. The 1% class has the largest number of cells followed for the 2% class. The 3% class decrease considerably the number of cells and then increase again in the 5% class. Hence the first three classes were selected as residual presence of *Nephrops* in the study area. Based on this a cut of at 3% was selected, this removed all VMS cells that have residual landings assigned to.

The result polygon aggregated the grid cells with at least 3% of the total *Nephrops* kg and at least 5 Km distance from neighbour cells (creation of geographical homogeneous areas); this area proved to be the best option, not too restrictive but enough to dismiss residual VMS points around the main ground. A buffer with a distance half of the cell size (1250 m) was applied to this result area, to include the whole raster cell rather than bisecting the centroid of the peripheral rasters (Figure 3.5).

Weighted overlay

Input values

Variables	Weight	Description
VMS	60	VMS aggregated 2010–2014, cut off 3%
UWTV survey densities	30	2013–2014
Sediment distribution	10	Stephens (2015) – sediment prediction model

Description: The weighted overlay method uses the three datasets as input values, scales those from 1 to 5 in order to have a common measurement scale and gives specific weight to each dataset according to each importance in the model. The GIS tool multiplies the raster cell of each dataset by the influence percentage, and adds to the other parameters cells that are in the same location. The weight percentage is used to reduce or increase the influence in the model.

Method to create polygon: The result of this method was a raster file with five classes, where each class represents the calculated *Nephrops* abundance. The raster converted into a polygon is represented in Figure 3.6.

Co-kriging

Input values

Variables	Description
VMS	Main variable, VMS aggregated 2010–2014, cut off 3%
UWTV survey densities	Covariable, 2013–2015
Sediment distribution	Covariable, Stephens (2015) – sediment prediction model

Description: The co-kriging input data types are point data (VMS and UWTV survey densities) and raster dataset (sediment distribution). The main variable is the VMS aggregated data while UWTV survey densities and sediment distribution are secondary variables used to make better predictions of the main variable. Co-kriging method was used to take advantage of the covariance between the variables that are geographically co-related with a given weights to each measurement based in the calculated semi-variogram. Those weights provide information to predict the unknown value in the location without VMS aggregated points.

Method to create polygon: The VMS data were interpolated using a "simple" co-kriging method, with a Normal Score transformation for each layer, a second polynomial function for the point data and a constant function for the sediment to detrend the data before the cross-covariance calculation. The semi-variogram was calculated using seven lags of 3.5 km length. To fit the semi-variogram a "Stable" function was used with a parameter of 2 and a major range value of 10 km (this is the distance where the values in the VMS dataset are no longer spatially correlated). Observed was a high spatial correlation between the VMS aggregated point and the *Nephrops* densities, while for sediment this correlation was weaker.

The model output (Figure 3.7A/B) is an interpolated raster file of 150x150 m with the predicted values from 0 to 1 (normalized VMS points of landed *Nephrops* kilograms). The final area was calculated using the contour line joining all cells with 0.03 predicted values. The cells with 0.03 values represent the locations where the predicted landings are 3% of the maximum *Nephrops* landed.

Using these new test areas a revision was done back to 2011, year where the effect of effort displacement is clearly visible (Figure 3.1). Test runs are presented in Table 3.1 where abundance estimates are provided using the original polygon and the new test polygons (still using the original 1.9% for Wigtown Bay and survey data 2013–2014, as this analysis was done prior to the 2015 UWTV Iris Sea survey). The fit to VMS data provided estimates that were in average 11% lower compared with the original abundance estimates, the weight overlay 6% lower and the co-kriging 2% lower. Final test polygons are shown in Figure 3.8.

Due to uncertainties in the <12 meter fleet behaviour an approach based exclusively on VMS data may be too restrictive and so not sufficiently comprehensive for the East Irish Sea where 12% of *Nephrops* directed vessels are <10 meters (2010–2014 data). There are areas where the presence of *Nephrops* is observed which don't have any VMS activity; there are no fishing restrictions in these areas and so the fishing activity might be not well mapped, reason why a method only based on VMS data might not be adequate.

The weight overlay method although uses information from all available datasets does not provide a good final fit compared with the other methods. It misses the top of the ground and also extends too far south, overlapping the wind farm area which is not currently fished. This method proved to be very sensitive to the weights given, thus is not considered to be a good method to use in this case. Due to the exclusion of this method no further runs were done using the 2015 survey data.

Based on this comparative analysis using three different approaches the co-kriging method seems the one that can currently provide a better fit to the available data in the main ground. The co-kriging approach seems to be the best approach as it takes into account all variables and is not as restrictive as the Fit to VMS model. The final polygon was updated including survey 2015 data which included new stations that were set to better define the boundaries of the main ground.

The total area (Km^2) was calculated for each model using different coordinator systems in Arc GIS 10 and the average value was taken for all approaches. Results are shown in the text table below with final results shaded.

MAIN GROUND	VMS FIT, 3% CUT OFF	WEIGHT OVERLAY (13–14 SURVEY DATA)	CO-KRIGING (13–15 SURVEY DATA)	PREVIOUS AREA
Europe Lambert conformal conic	930.2	932.97	1019.49	
British National Grid	930.63	933.44	1019.99	
UTM 30N	930.57	933.38	1019.9	
Average area (Km^2)	930.47	933.26	1019.79	1032.75
Wigtown Bay	VMS fit, 3% cut off	Previous area		
Europe Lambert conformal conic	67.21			
British National Grid	67.22			
UTM 30N	67.22			
Average area (Km^2)	67.22	19.62		

For Wigtown Bay the 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 (Wigtown Bay: VMS 2010–2014 with 3% cut off, buffer to define the polygon using 100 m from the edge VMS points). There was a substantial increase of the fishing area in this northern ground which is currently around 6.6% of the main ground (1.9% prior to the construction of the wind farm). Based on VMS data it was estimated that from all landings (within the new defined area) in Wigtown Bay, 65% are *Nephrops*; this clearly shows that Wigtown Bay is used by the industry as a *Nephrops* target ground. In the main ground *Nephrops* represents 73.27% of the total landings.

Wigtown Bay in relation to Main ground:

2008 ESTIMATION	0.019
IBP Nep 2015	0.066

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. Figure 3.9 shows the final estimated areas for both grounds.

Final updated abundance burrow density estimates are presented in Figure 3.10 (and Table 3.2) where the geospatial model was updated using the new area based on the co-kriging approach (1019.79 Km^2) and the extrapolation to Wigtown Bay using 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 a 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			IBP 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	

Table 1.1. Irish Sea East (FU14): Landings (tonnes) by country, 2000–2014.

Year	Rep. Of Ireland	UK	Other Countries	Total
2000	114	451	2	567
2001	26	506	0	532
2002	203	373	1	577
2003	69	306	1	376
2004	62	409	1	472
2005	34	536	0	570
2006	34	594	0	628
2007	86	873	0	959
2008	29	652	0	681
2009	16	692	0	708
2010	45	538	0	583
2011	31	530	0	561
2012	53	478	0.123	530
2013	35	460	0.195	495
2014	31	648	0	679

Table 3.1. Irish Sea East (FU14): Test runs for the geospatial model using the polygons generated by all tested approaches: Fit to VMS, weight overlay and co-kriging. Abundance estimates are provided using the original polygon and the new test polygons. In these runs the addition for Wigtown Bay was made by still using 1.9% and survey data including 2013 and 2014.

2015	Abundance	Addition for Wigtown (1.9%)	% change in relation to original ground	Mean Krigged density (no./m²)
Original polygon	554.1	564.7		0.537
Fit to VMS points	492.4	501.7	-11	0.599
Weighted overlay	517.2	527.1	-7	0.558
Co-kriging	540.6	550.8	-2	0.557
2014				
Original polygon	424.4	432.5		0.39
Fit to VMS points	375.2	382.3	-11	0.456
Weighted overlay	398	405.5	-6	0.429
Co-kriging	411.7	419.6	-3	0.424
2013				
Original polygon	457.0	465.7		0.44
Fit to VMS points	407.8	415.6	-12	0.496
Weighted overlay	435.8	444.1	-6	0.47
Co-kriging	444.6	453	-4	0.458
2012				
Original polygon	640.5	652.7		0.62
Fit to VMS points	573.5	584.4	-9	0.698
Weighted overlay	597.6	609	-5	0.645
Co-kriging	634.1	646.1	1	0.653
2011				
Original polygon	423.0	431.0		0.41
Fit to VMS points	375.2	382.3	-11	0.456
Weighted overlay	399.1	406.7	-6	0.431
Co-kriging	410.4	418.2	-3	0.423

Table 3.2. Irish Sea East (FU14): Results from NI/ROI/E&W collaborative UWTV surveys of *Nephrops* grounds in 2007–2015. Final abundance estimates are adjusted with a relative to absolute conversion factor of 1.2 and a 1.9% raising factor for Wigtown Bay area in 2008–2010 and 6.6% in 2011–2015.

Year	No valid stations	Mean Krigged density (no./m²)	Abundance (millions) including Wigtown Bay (1.9% 2008–2010; 6.6% 2011–2015)	95% CI	CV	Landings	Removals (millions)	HR
2007	--Unreliable data---							
2008	32	0.38	407.6	63.0		676	28.1	6.90%
2009	32	0.33	350.0	76.0		707	20.0	5.72%
2010	26	0.4	422.0	103.0		582		
2011	26	0.41	449.2	98.8	11.8%	561		
2012	26	0.64	693.8	99.0	7.8%	530		
2013	31	0.45	487.0	81.6	9.1%	495	29.3	6.01%
2014	34	0.41	449.1	91.8	10.7%	679	33.6	7.49%
2015	42	0.54	590.5	86.0	7.9%			

4 Review of FU14 stock parameters, fishery data and raising procedures

Commercial landings are supplied by the UK, Ireland and occasionally by Belgium. The quality of the historical landings data is not well known but they are perceived to be slightly misreported. The introduction of the buyers and sellers legislation in 2006 by the UK did significantly improved the reported landings.

Due to concerns around the level of effort reporting, lpue 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.

Sampling biological data are only supplied by UK-England. The sampling intensity for this area has been historically low, been almost inexistent during 2010, 2011 and 2012. Number of samples increased again in 2013, when the *Nephrops* sampling programme was reinstate by Cefas.

There were identified three sampling programme 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).

Note: length–weight parameters, growth parameters, maturity and natural mortality were presumably not updated due to a lack of new data.

Nephrops catch sampling

The *Nephrops* catch sampling was set up by Cefas to complement the market sampling programme in 1999 and to improve the biological sampling targeted to *Nephrops* in the East Irish Sea. This sampling programme stopped during 2009 and 2010. In 2011 there were efforts to reinstate this sampling programme but only in 2013 the sampling intensity increased. It currently provides samples during the high catching seasons (Q2 and Q3).

This programme relies on the industry cooperation. Vessels are requested to provide samples of unsorted catch that are collected when vessels land in Whitehaven port (Table 4.1). Length and sex composition is provided for this catch samples and additionally, in an irregular basis, length–weight and maturity data are also collected.

Observer programme

Under the DCF requirements for data collection samples have been provided for the East Irish Sea since 2003. This sampling programme involves having observer onboard of commercial vessels to get the length and sex composition for the retained and discarded component. Due to a random selection of vessels the number of *Nephrops* trawlers sampled in each year varies and usually is not sufficient by its own to provide enough samples to assess this stock and to derive the annual landing length distribution (Table 4.2).

Market sampling

Market sampling data are available since 1983. Here landings are sampled after being landed in the market and, crucially, usually after being graded. There are potentially significant issues related with tailing and of this category being misrepresented (i.e. missing) in the samples. This can be seen in the overall length distributions which are skewed towards the higher grades. Results were discussed at WGCSE 2015 and it was agreed that these dataset would not be suitable to raise the total landing data as they are biased towards the bigger size classes. Additionally from 2010 there are very few samples available for *Nephrops* FU14 (Table 4.3).

- As agreed in WGCSE 2015 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 (Figure 4.1).
- A threshold of a minimum of 50 animals measured per sample was used to discard any samples with very low measurements.
- Data from the catch sampling programme were 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.

4.1 Review Mean Length/Weight for landings and discards

The current annual mean weight in the landings (Table 4.1.1) is calculated from the length–frequency data provided by a combination of the catch sampling programme - observer programme and Hossein *et al*. (1987) length–weight relationship. No updates were made to the length–weight relationship.

By using the combination of these two sampling programmes length frequencies were recalculated historically up to the year 2000 (Figure 4.2). Table 4.1.1 shows the updated mean length and weight combined by sex for total annual landings and discards. Values for 2010, 2011 and 2012 are not reliable due to poor sampling and so not presented.

Previous estimations of mean weight in landings were made by using a combination of the market sampling and catch sampling data and this explains the reduction of the new estimated values as the market sample length distribution is biased towards the bigger size classes.

4.2 Sex ratio

Previous *Nephrops* working groups have highlighted stability in sex ratio as an important indicator for *Nephrops* stocks and it is recommended that sex ratio indicators should be updated and revised annually. The sex ratio was revised in this IBP and shows a cyclical pattern which might be linked to female emergence behaviour but also due to low sampling numbers which might influence this result. Assuming the sampling levels for 2013 and 2014 were adequate the estimated proportion of males is close to 50% and so it is expected a quite even exploitation between sexes for the current East Irish Sea fishery.

Figure 4.2.1 shows the proportion of males since 2000 up to 2014. Between 2010 and 2012 due to poor sampling levels estimates of sex ratio are not reliable.

4.3 Discard selection

From 2002 onwards the observer programme has been used to determine the discard ogive for FU14. Under this IBP process the discard ogive was updated but no significant difference was noticed in the estimated mean weights for landings and discards. Figure 4.3.1 shows the comparison of the annual mean weight for landings and discards produced by using the former discard selection parameters (L50=24.006 and L25=25.235) and the new parameters (L50=23.54 and L25=24.77).

Figure 4.3.2 shows the discard selection on an annual basis since 2003, although there are variations annually 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 4.3.3), which shows a selectivity at higher sizes compared with FU15.

4.4 Discard selection survival rate

During the WGCSE 2015 it was agreed that the discard survival rate should be updated form 0% to 10%. Although there are no direct survivability studies available for this area it is expected that the survivability of discarded animals should be similar to the fishery in FU 15 where fishing practices are similar and both are largely spring/summer fisheries and animals discarded are exposed to warmer temperatures before returned to sea. Densities in FU15 are generally higher than FU14 so it would be expected a lower survivability in FU15 than FU14, although this might be balanced with the fact that small vessels in FU14 tend to sort the last tow while either heading back to port (therefore increasing the chances of discarding outside suitable habitat) or more often actually inside the port and since the main landing port of Whitehaven is gate locked the survivability is expected to be none. Based on this rational it was agreed during the WGCSE 2015 that 10% would be a reasonably good estimation for this stock. This parameter should be revised if any survivability experiments take place in the Irish Sea. Also exploratory analysis can be done in a future benchmark regarding sensitivity analysis and how these parameters influence the SCA outputs.

Table 4.1. Irish Sea East (FU14): Summary of the catch sampling programme (catch component) showing number of samples and animals measured since 1999.

	Number of samples					Number of *Nephrops* measured							
Year	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	B	F	M	Total
1999				4	4				996	29	329	638	996
2000	9	2	3		14	2239	432	738		15	1328	1821	3409
2001		4	8		12		931	1875		39	1375	1392	2806
2002	7	2	4		13	1635	476	855		21	813	1968	2966
2003		4			4		1171			1	750	197	1171
2004	5	15	4		24	917	2794	1424	281	6	2526	2347	5416
2005		6	4		10	688	743	1208			855	839	2639
2006		5			5		766			12	431	323	766
2007	2				2	795					229	341	795
2008		3			3		1284			6	349	487	1284
2009					0								
2010					0								
2011		2			2		658			26	126	506	658
2012			5		5			575			321	254	575
2013		19	7		26		4424	2456		22	2979	3879	6880
2014		16	10		26		3188	1756		14	2730	2200	4944

Table 4.2. Irish Sea East (FU14): Summary of the observer sampling programme. Numbers outside brackets refer to total samples/animals measured for the retained component, while the numbers for the discard component are within brackets. Samples are provided since 2003.

Year	Number of samples – Retained and (Discarded)					Number of *Nephrops* measured – Retained and (Discarded)				
	Q1	Q2	Q3	Q4	TOT	Q1	Q2	Q3	Q4	TOT
2003		3 (1)		1	4		581 (2)		1	584
2004	2	2 (2)	4 (3)		8	580	2074 (56)	962 (115)		3787
2005	1 (1)				1	475 (8)				483
2006			1 (1)		1			240 (6)		246
2007	2 (1)	11 (10)	4 (4)	2	20	453 (41)	6239 (1128)	1674 (204)	413	10152
2008	5 (5)	12 (8)	5 (4)	3 (2)	26	1464 (456)	2206 (197)	3239 (325)	284 (22)	8193
2009		6 (2)	2 (1)	2 (2)	10		1316 (159)	248 (68)	265 (12)	2068
2010	1 (1)	3 (3)		(1))	5	94 (48)	756 (50)		((2)	950
2011			3 (1)		3			774 (10)		784
2012	2 (1)	2	4 (1)		8	265 (82)	21	373 (4)		745
2013	1	1 (1)	2 (2)	1 (1)	5	122	121 (8)	375 (59)	121 (57)	863
2014		3 (2)	3 (3)		6		602 (103)	595 (71)		1371

Table 4.3. Irish Sea East (FU14): Summary of the market sampling programme (landings component only) showing number of samples and animals measured since 1983.

Year	Number of samples					Number of *Nephrops* measured					Mean CL Length sample
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total	
1983	0	12	17	6	35	0	544	811	217	1572	35.3
1984	0	8	19	1	28	0	339	835	38	1212	33.7
1985	0	8	17	0	25	0	322	729	0	1051	32.9
1986	0	8	16	0	24	0	319	687	0	1006	32.6
1987	0	12	4	1	17	0	365	154	34	553	36.9
1988	0	12	6	0	18	0	378	251	0	629	38.0
1989	0	3	0	0	3	0	108	0	0	108	35.8
1990	0	1	2	0	3	0	32	82	0	114	36.9
1991	0	2	11	0	13	0	91	957	0	1048	34.2
1992	0	13	14	5	32	0	987	983	406	2376	34.2
1993	5	9	8	0	22	238	843	930	0	2011	36.2
1994	0	5	6	0	11	0	432	661	0	1093	36.3
1995	1	6	6	0	13	75	496	600	0	1171	34.9
1996	0	6	5	1	12	0	569	493	58	1120	35.9
1997	0	5	3	0	8	0	350	259	0	609	34.2
1998	2	3	4	1	10	113	205	367	89	774	32.7
1999	2	8	7	1	18	136	610	536	40	1322	35.9
2000	4	10	8	3	25	244	761	816	99	1920	37.4
2001	2	7	10	11	20	69	575	874	43	1561	35.2
2002	4	8	10	0	22	247	488	889	0	1624	36.0
2003	6	8	10	0	24	185	446	854	0	1485	38.4
2004	5	8	5	0	18	330	641	482	0	1453	36.0
2005	2	5	3	0	10	106	504	250	0	860	36.8
2006	1	1	2	0	4	55	125	125	0	305	36.8
2007	1	4	14	6	25	75	326	1278	611	2290	35.1
2008	5	13	10	1	29	273	837	978	75	2163	34.8
2009	4	8	8	5	25	191	695	787	406	2079	34.7
2010	2	3	0	1	6	140	241	0	74	455	34.8
2011	0	0	1	1	2	0	0	66	25	91	34.1
2012	1	1	2	0	4	25	43	103	0	171	39.9
2013	0	0	0	0	0	0	0	0	0	0	0
2014	0	6	2	0	8	0	369	137	0	506	36.5

Table 4.1.1. Irish Sea East (FU14): Mean length and weight combined by sex for total annual landings and discards. Values for 2010, 2011 and 2012 are not reliable due to poor sampling.

Year	MeanLenLand	MeanLenDisc	MeanWtLand	MeanWtDisc
2000	29.83	22.32	19.05	7.52
2001	30.59	22.74	20.87	7.97
2002	30.64	23.75	22.41	8.98
2003	33.69	22.43	29.12	7.62
2004	31.01	22.24	21.93	7.57
2005	30.74	23.16	21.48	8.44
2006	32.36	22.75	25.07	7.98
2007	31.81	21.92	23.94	7.33
2008	31.07	23.14	22.88	8.49
2009	35.57	23.21	36.49	8.58
2010	-	-	-	-
2011				
2012				
2013	30.14	22.43	19.94	7.87
2014	31.01	24.34	22.37	9.60

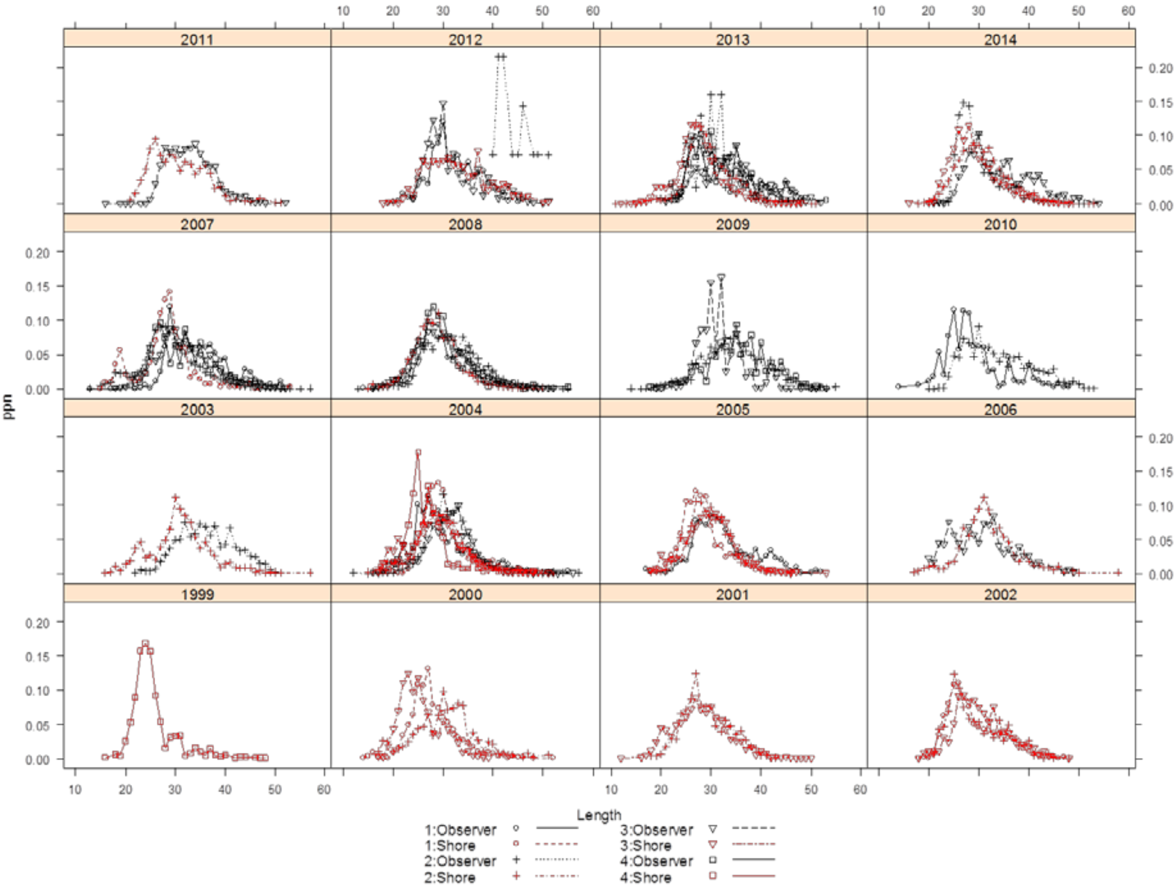


Figure 4.1. Irish Sea East (FU14): Length distribution of samples from the observer programme (black lines) and the catch sampling programme (red lines), 1999–2014. Length frequency for 2010–2012 is based in very poor sampling so not reliable.

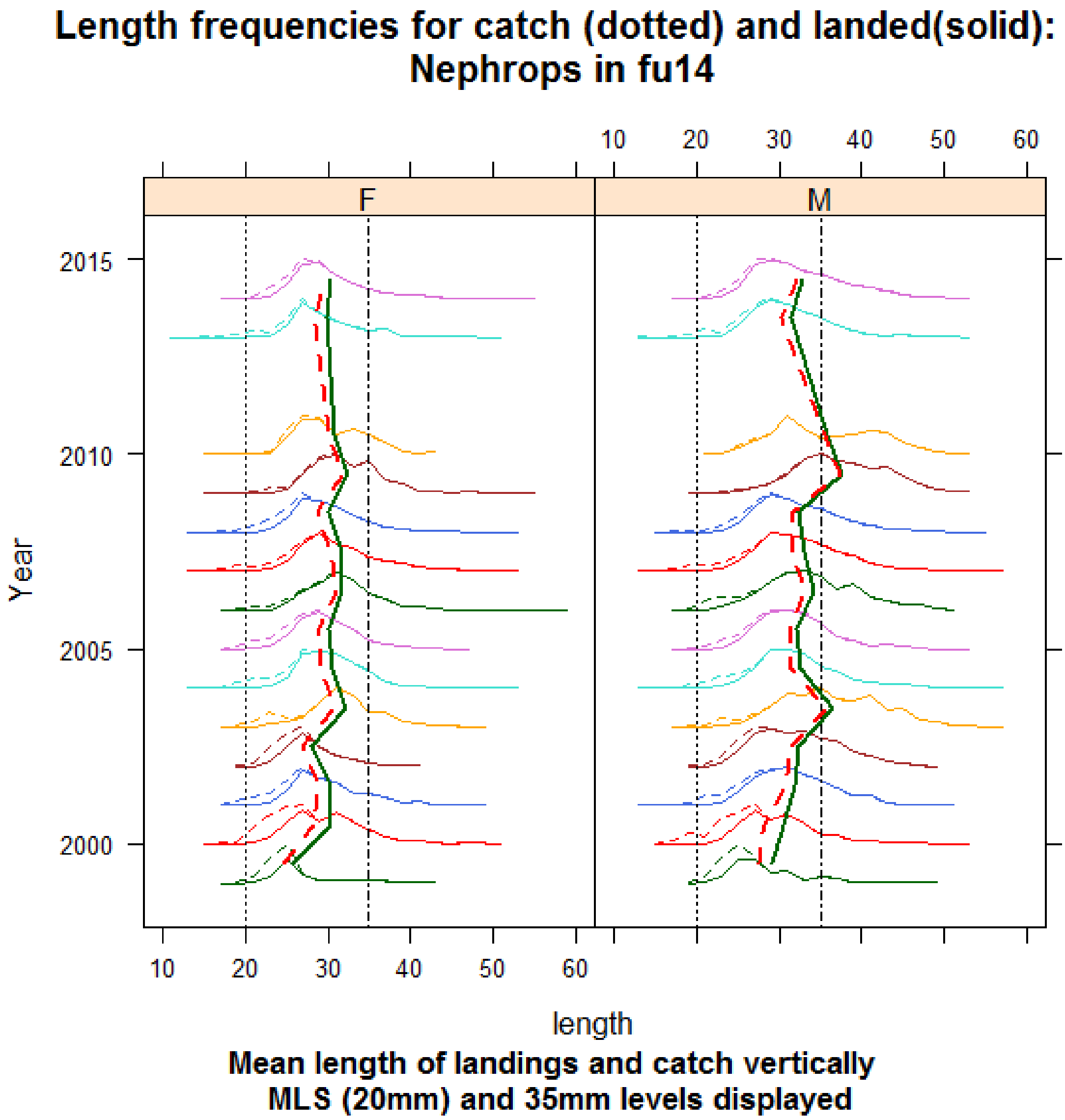


Figure 4.2. Irish Sea East (FU14): Length distribution of landings (solid lines) and catch (dotted lines), 2000–2014. Length frequency for 2010 is based in very poor sampling so not reliable.

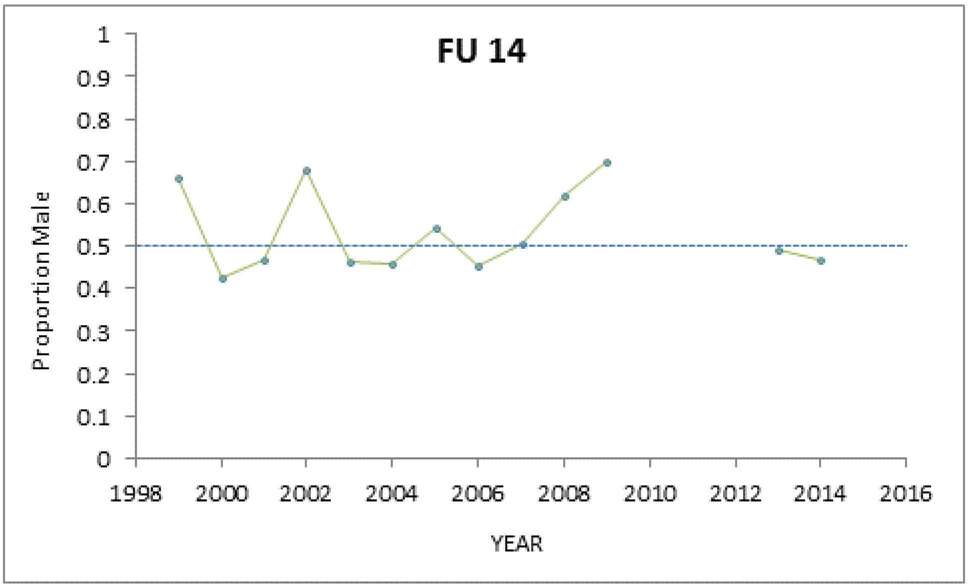


Figure 4.2.1. Irish Sea East (FU14): Proportion of males since 2000. Between 2010 and 2012 due to poor sampling levels estimates of sex ratio are not reliable.

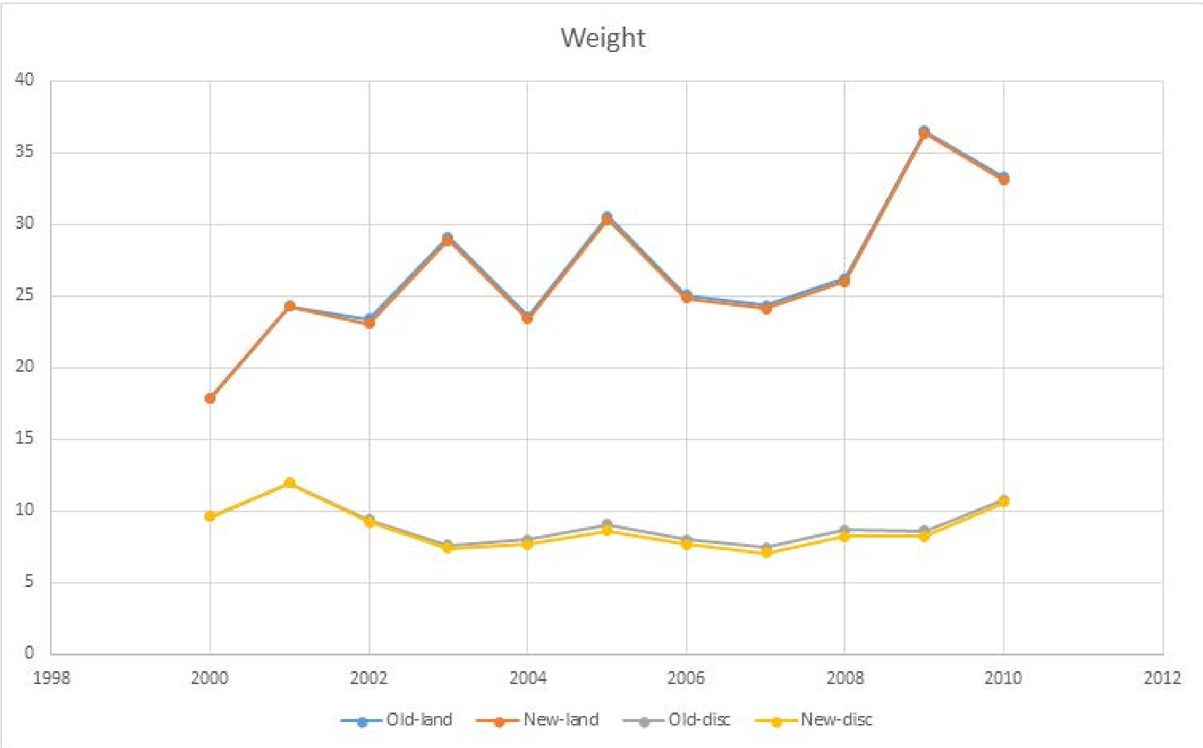


Figure 4.3.1. Irish Sea East (FU14): comparison of the annual mean weight for landings and discards produced by using the former discard selection parameters (L50= and L25=) and the new parameters (L50=23.54 and L25=24.77).

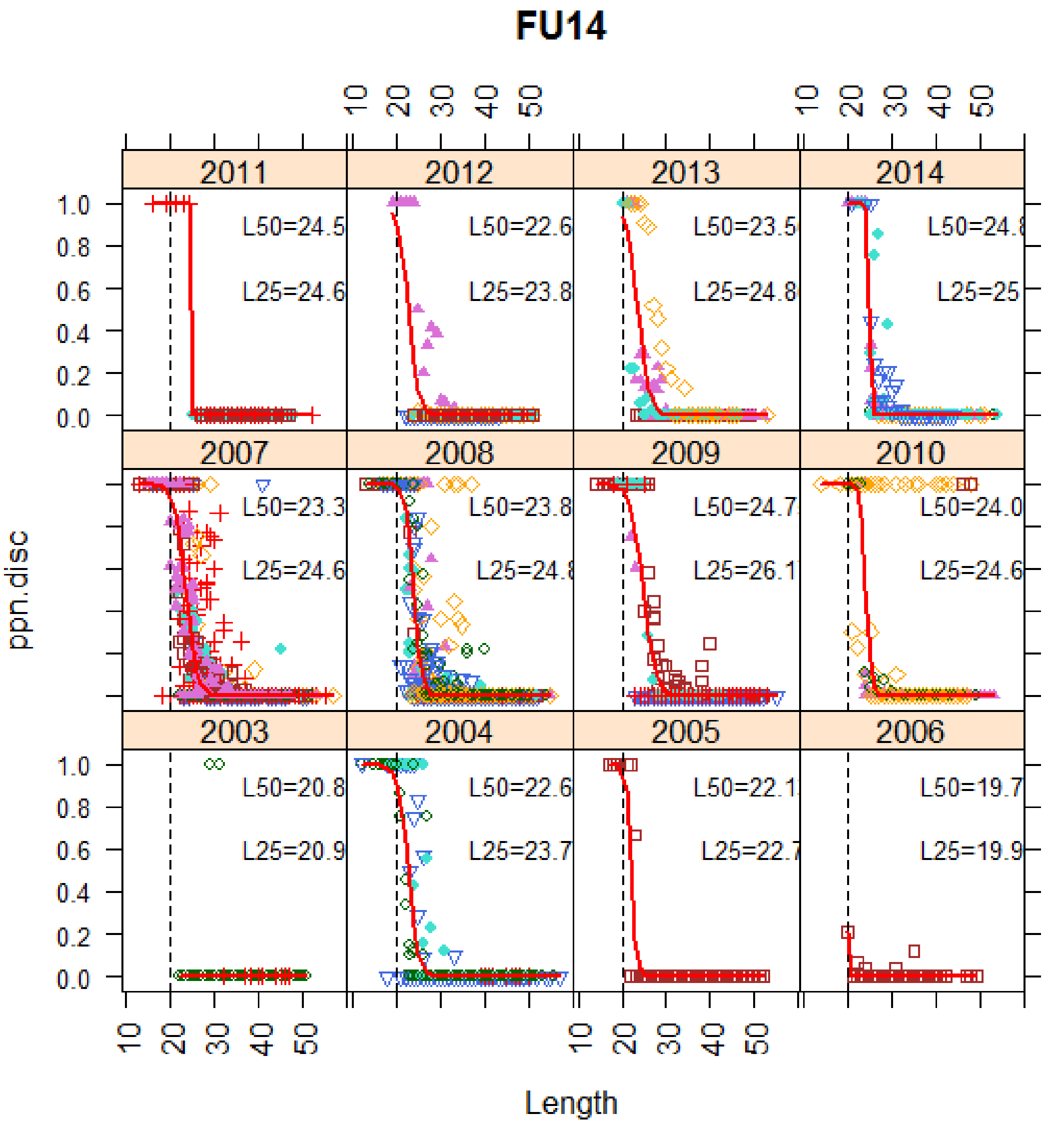


Figure 4.3.2. Irish Sea East (FU14): Annual discard ogives, 2003–2014.

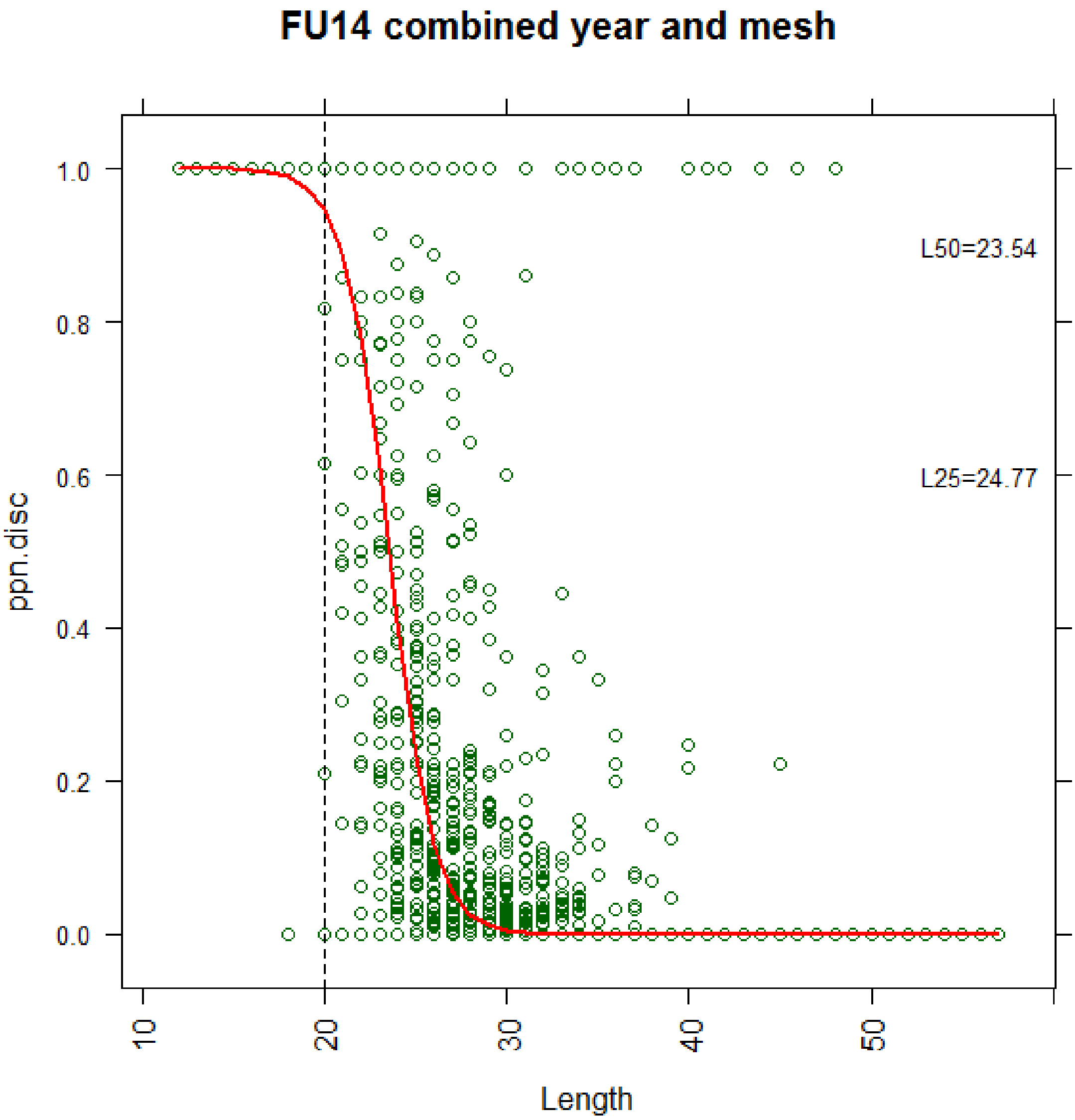


Figure 4.3.3. Irish Sea East (FU14): Final discard ogive pooled for all years and mesh sizes. L50=23.54 and L25=24.77.

5 Review of FU14 Reference points

MSY explorations

New MSY explorations were carried out at the current IBP for FU14. A SCA (separable cohort analysis, model Bell) was used to estimate sustainable stock-specific Harvest Ratio reference points.

Input values as follows:

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	"

The results of the SCA model carried out in 2010 and in 2015 are given in the text table below. Three stock-specific candidates for F_{MSY} ($F_{0.1}$, $F_{35\%SPR}$ and F_{MAX}) were derived from this length-based per recruit analysis. The text table shows the F multipliers required to achieve the potential F_{MSY} proxies, the harvest rates that correspond to those multipliers and the resulting level of spawner per recruit as a percentage of the virgin level. YPR curves and other plots generated by the model are shown in Figure 5.1.

Calculated in WG 2010 – F_{MSY} = 9.8% ($F_{0.1}$ combined)						
		F_{BAR} 20–40 mm		Harvest Rate	Virgin spawner per recruit	
		Female	Male		Female	Male
	Combined	0.1	0.14	9.8%	45%	43%
$F_{0.1}$	Female	0.11	0.15	10.2%	44%	41%
	Male	0.1	0.14	9.6%	45%	43%
	Combined	0.14	0.2	13.0%	36%	33%
$F_{35\%Spr}$	Female	0.15	0.21	13.5%	35%	32%
	Male	0.14	0.19	12.5%	37%	35%
	Combined	0.2	0.28	16.4%	29%	26%
F_{MAX}	Female	0.21	0.3	17.4%	27%	25%
	Male	0.19	0.26	15.8%	30%	27%

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

- Density of *Nephrops* in FU14 is considered moderate (~0.49 burrow/m², average 2011–2015).
- The area covered by this fishery is relatively small and the confidence intervals for the abundance estimate are large for a geostatistical survey due to the sample density.
- The perception in the Irish Sea is that the growth rates in the eastern Irish Sea are similar to those in the western Irish Sea but the mean sizes (CLmm) in each fishery are markedly different, with the eastern Irish Sea *Nephrops* being the larger.
- Current exploitation rates are even for both sexes.
- Current Harvest Ratio for 2014 was estimated at 7.49% and the F_{sq} (2013–2014) at around 6.7%.

Based on the fact that some biological parameters are poorly known; inconsistent biological sampling; uncertainties about the stability of the stock over the reference period and uncertainties about the variability of recruitment 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. Currently this fishery is being harvest at 6.7% (F_{sq}_2013–2014 = 6.7%; F_{2013}= 6.01%; F_{2014}= 7.49%), and historically the available data show a maximum harvest rate of 8.2% in 2008 which are below the F_{MSY} proxy.

Year		Harvest Rate
2008		8.20%
2009		5.72%
2010	NA	
2011	NA	
2012	NA	
2013		6.01%
2014		7.49%

2010–2012: No harvest rate values provided due to poor sampling.

MSY $B_{trigger}$

MSY $B_{trigger}$ is intended to safeguard against an undesirable or unexpected low SSB when fishing at F_{MSY} and is considered the lower bound of SSB fluctuations around B_{MSY}. For *Nephrops* stocks MSY $B_{trigger}$ has been defined as the lowest stock size from which the abundance has increased. Accordingly with this definition $B_{trigger}$ is set for FU14 as 350 million, corresponded to the abundance observed in 2009 (Figure 5.2).

The reference points set under IBP Nep14 might be subjected to a future revision based on the outcomes of WKMSYRef4 (13–16 October 2015).

Other reference points

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).

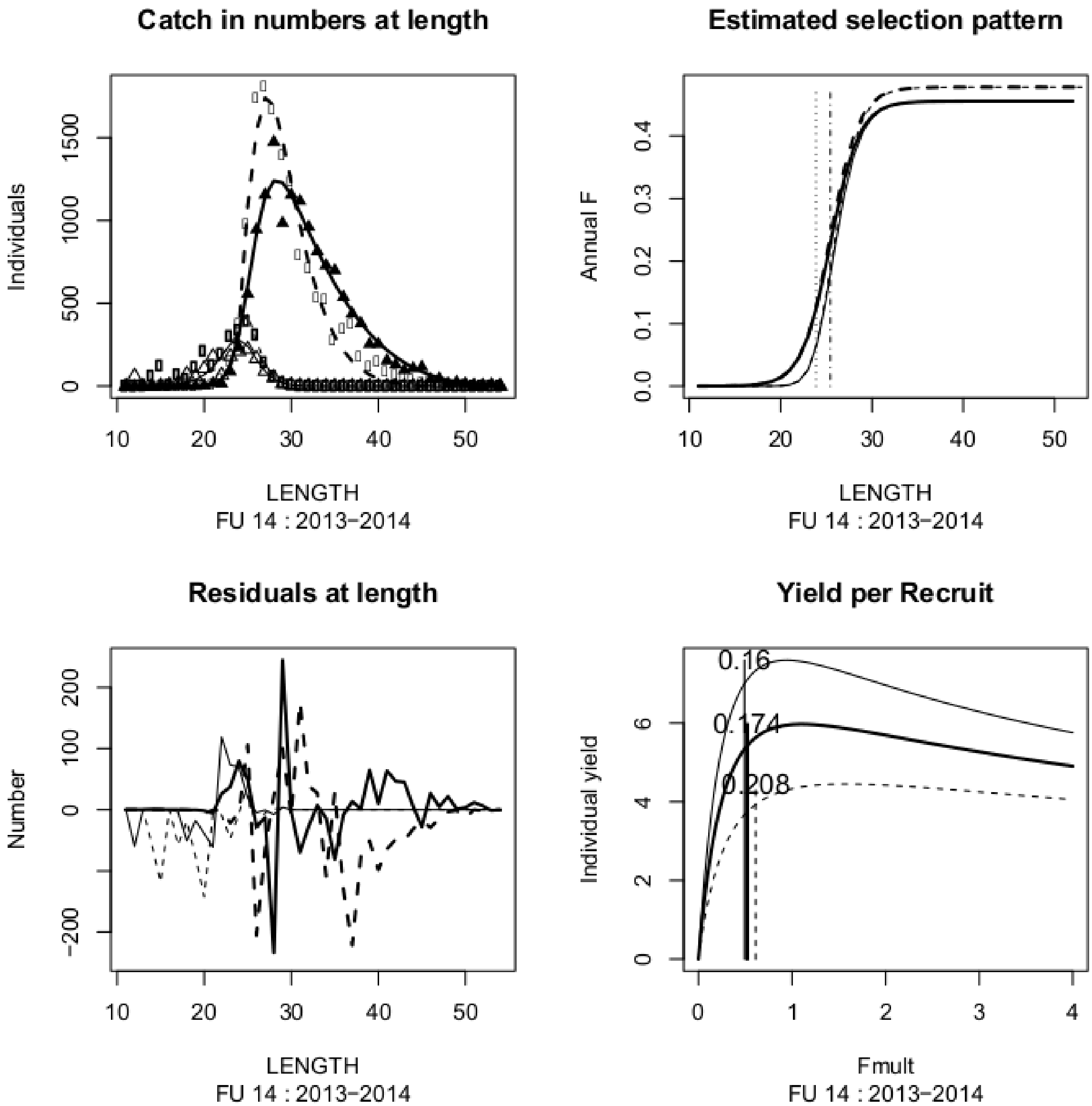


Figure 5.1. Irish Sea East (FU14): Separable Cohort analysis (SCA) model fit from 2015 analysis. Solid lines are for males, dashed lines are females, thick lines represent the landings component, and the thin lines represent the discarded component. The top left panel gives observed and predicted numbers-at-length in the discards and landings, top right gives the fishing mortality-at-length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed–expected) at length. The bottom right gives the Yield-per-recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.

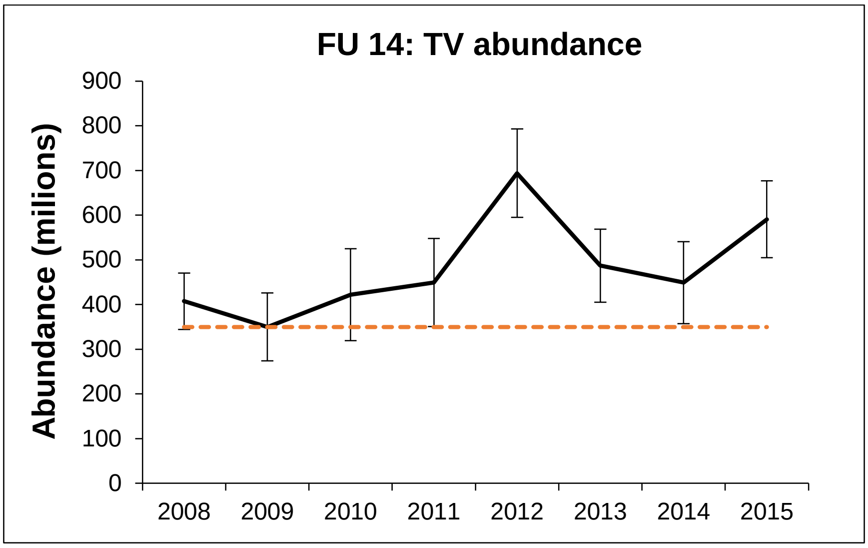


Figure 5.2. Irish Sea East (FU14): Burrow density estimates from the UWTV Survey 2008–2015. MSY $B_{trigger}$ presented as a red line.

6 FU14 inputs and methodology for catch options

An estimate of mean weight in the landings and discards is required to calculate catch options using the methodology developed by WKNEPH (ICES, 2009). Although the standard procedure recommends the use of a three year average, it was agreed by WGCSE 2015 that in this case due to poor sampling prior to 2013 the average of two years would be adequate (2013–2014).

Previous estimations of mean weight in landings were made by using a combination of the market sampling and catch sampling data and this explains the reduction of the new estimated values as the market sample LD is biased towards the bigger size classes.

mean weight discards	14.1	(2006–2008)
mean weight landings	28.9	(2006–2008)
mean weight discards	8.6	(2013–2014)
mean weight landings	21.3	(2013–2014)

Catch option table inputs under the landing obligation scenario are given in the text table below. A two year average (2013–2014) of mean weight in the landings/discards and proportion of removals retained was used. This will be presented in October 2015 for the provision of advice for 2016.

	Harvest ratio	Catch	Wanted catch	Unwanted catch
Fsq_2013–2014	6.7%	780	734	46
Fcurrent (2014)	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

INPUT		
Survey Abundance (Millions)	590.5	UWTV Survey 2015
Cumulative absolute conversion factor	1.2	As per WKNEPH 2009 (See Annex)
Mean weight in landings (g)	21.27	Sampling 2013–2014
Mean weight in discards (g)	8.61	Sampling 2013–2014
Total discard rate	13.4%	Sampling 2013–2014
Prop of removals retained by the fishery	0.866	Sampling 2013–2014
F_{MSY} approach	11.00%	IBP 2015
$B_{trigger}$	350	IBP 2015

7 Future Research and data requirements for FU14

As in other *Nephrops* stock there are a number of generic research questions related to occupancy and edge effect bias that needs still to be investigated. But there are also specific uncertainties and assumptions that need to be examined further for the East Irish Sea before less conservative F_{MSY} proxies could be considered.

- More accurate mapping of the spatial extent of the grounds and fisheries, this includes having positional data for <12 meter vessels and more survey data in Wigtown Bay area to better define this ground.
- Improvement of spatial coverage and sampling of landings and discards, this includes increasing the sampling levels to covers Northern Irish vessels, as the current sampling is mainly focused on local vessels form Whitehaven port.
- Area specific length–weight and maturity data to validate the parameters used for this FU.
- Better knowledge of the difference in growth and population structure across the area.

8 Review of *Nephrops* ground area in FU17

8.1 VMS, Seabed mapping, fishery dependant and survey data

In FU17 *Nephrops* are caught on a three discrete grounds locally called Aran grounds, Galway Bay and Slyne Head (Figure 8.1.1). IBPNeph redefined the area of these discrete polygons using a range of data sources similar to that procedure carried out for *Nephrops* patches in FU 19 (WKCELT, 2014) (Table 8.1.1). Integrated VMS-logbook 2006–2014 databased on the methods described in Gerritsen and Lordan (2011) where *Nephrops* directed activity was defined for VMS pings where >30% of daily operational landings was reported to be *Nephrops*. Also available MBES backscatter (multibeam echosounder) data from the Irish National seabed mapping programme (www.infomar.ie) was overlaid on the VMS data to further refine the limits of the Aran in particular but also of the other smaller grounds (Figure 8.1.2). The MBES backscatter data indicates sediment hardness where soft substratum produces light grey colouration whereas harder substrata appears darker as acoustic signal returns strongly from a hard surface and is absorbed in soft ground. Other data such as groundfish survey stations with *Nephrops* catches, cpue data from on-board observer trips, sediment PSA data, (particle size analysis) from infomar and UWTV stations were also mapped to check boundaries of the polygons (Figure 8.1.1). The revised polygons were manually drawn and the area calculated using different projections in Arc GIS 10.

Aran Grounds

VMS and backscatter data overlays and how this is used to redefine the Aran eastern edge are depicted in Figure 8.1.4. The distinct area of light grey indicates softer sediment and links well with the VMS pattern of *Nephrops* landings where red=0% N*ephrops*; blue=50-60% *Nephrops*, green=90% N*ephrops*. There is evidence of a gradual decline in landings (observer cpue data and VMS data) which corresponds to the low % of mud observed from particle size analysis of sediment samples obtained from UWTV surveys (Figure 8.1.3). Also the TV densities observed here are generally lower where there is less suitable habitat for the construction of *Nephrops* burrows. All of these data combined with the zero density TV observations were used to redefine this part of the ground.

Backscatter and VMS data overlays for the northern edge (Figure 8.1.5) were used mainly to define this edge where there is a sharp transition from soft to hard sediment. The sharp transition links with the VMS pattern of high to low *Nephrops* landings. The backscatter data shows some fingerlings of soft sediment jutting out and the area was redefined to take account of these where zero density UWTV observations were also incorporated as the cut-off point.

Figure 8.1.6 illustrates that there is a sharp transition from soft to hard sediment in the southwest of the Aran which corresponds to the VMS data and the backscatter data.

Galway Bay

Data overlays for Galway Bay show some linkages mainly where there is a clear transition from soft to harder sediment. However, the backscatter data for Galway Bay shows a large area of soft sediment which may not be *Nephrops* habitat (Figure 8.1.7). A meeting was held with a local skipper to discuss the Galway Bay ground limits showing the revised boundary based on scientific data sources. The industry knowledge and information was used to define the ground. Figure 8.1.8 shows the industry boundary compared to the initial scientific boundary highlighting the importance of dialogue between industry and scientists in discussing stock issues.

Slyne Head

VMS and recently obtained backscatter data show a strong for the eastern part of this ground (Figure 8.1.9).These data and mainly the VMS was used to define this ground. The new ground boundary was used to re-estimate the historical time-series of abundance.

Conclusion on area

The revised areas of each discrete polygon is shown in Table 8.1.2 using different projections in Arc GIS 10 and the average value is taken as the final area. The redefinition of the polygons in FU17 resulted in ~30% increase in overall area from 1007 km² to 1320 km² (Table 8.1.3). **IBPNeph concluded that the new area estimates should be used to generate total abundance for *Nephrops* on each patch in FU17 and the historic time-series should be revised accordingly.**

The IBP also noted that other data sources such as groundfish surveys and observer trips show catches of *Nephrops* outside the defined patches, however, these are deemed to be minor at present. IBPNeph recommended that the area boundaries should only be refined when substantial additional data becomes available (e.g. new backscatter data, sediment sampling data and improved VMS data to include vessels of size 12 metres). Any future area revisions should be considered by WGNEPS.

The shapefiles of the FU17 ground are available at: http://www.isde.ie and also http://data.marine.ie/downloads/fisheries/NephropsGrounds.zip.

8.2 Larval tracking models

Adult *Nephrops* are territorial and not thought to undergo much movement on the seabed so that adult populations can be considered as separate stocks. Recent larval tracking studies using both Regional Ocean Modelling System (ROMS) and a larval transport model (LTRANS) for *Nephrops* in the Celtic Sea has explored the potential connectivity between proximal and distant *Nephrops* grounds (O'Sullivan *et al.*, 2015). This study differentiated between larval retention and dispersal as there are important consequences for stock connectivity. The study demonstrated that the *Nephrops* grounds in FU17 are linked in a metapopulation state whereby some grounds are donors of larvae and others retainers. A connectivity matrix table presented by O'Sullivan *et al*. describes the percentage of larvae that are retained over the same ground from which they are hatched or transported to adjacent grounds following the pelagic larval phase. From the study Aran Grounds retains larvae but also donates to both the Galway Bay and Slyne Head grounds and conversely Galway Bay and Slyne Head retains larvae and also donates to the main Aran ground. Benchmark concluded that the results from this study were important to stock assessment demonstrating the inter-connectivity of the *Nephrops* grounds in FU17.

8.3 Historical UWTV survey data corrections

The distance over ground calculations in MS Access were refined and checked so that for all years and grounds the counted distance was used to calculate distance. This correction process resulted in revisions to the dataset used in the krigging analysis.

Table 8.3.1 shows the % difference in the distance over ground calculations. Main revisions occur in the first years of the time-series for Aran grounds and revisions are low. For Galway Bay a similar pattern occurs where revisions are mainly in the early years and this also applies to Slyne Head. This is attributable to the development stages of the data handling and storage system for UWTV dataset.

Currently each survey year has a local MS Access database and when the data are final and passed quality control, they are then uploaded to a central database housed on a SQL server.

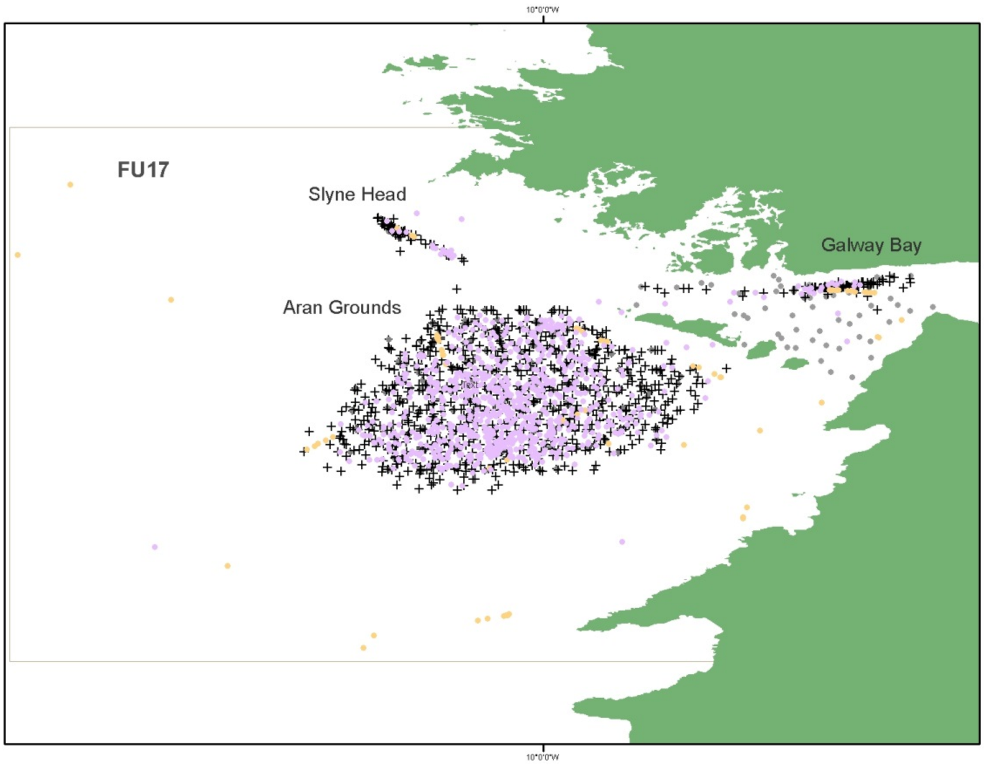


Figure 8.1.1. ***Nephrops*** **in FU17.** ***Nephrops*** **ground in FU17 and data sources mapped. TV densities (black cross), sediment PSA samples (grey dots), observer cpue data (purple dots) and IGFS cpue data (orange dots).**

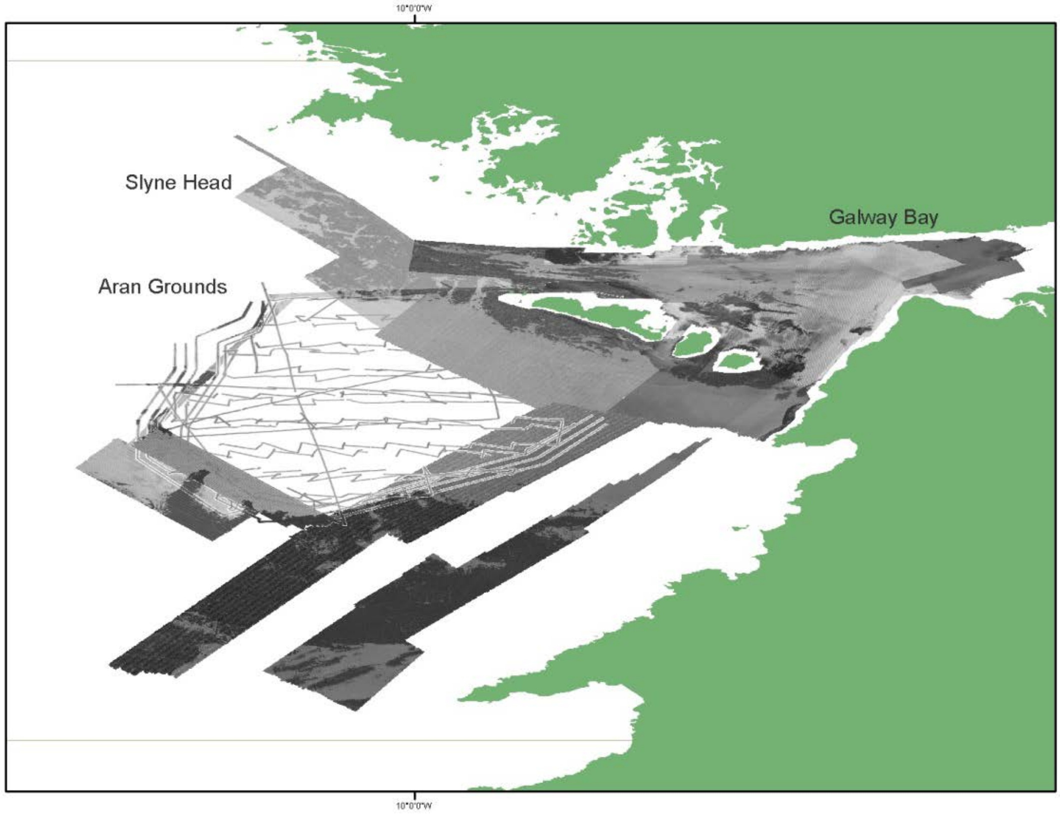


Figure 8.1.2. *Nephrops* in FU17. Available backscatter data from various seabed mapping programmes.

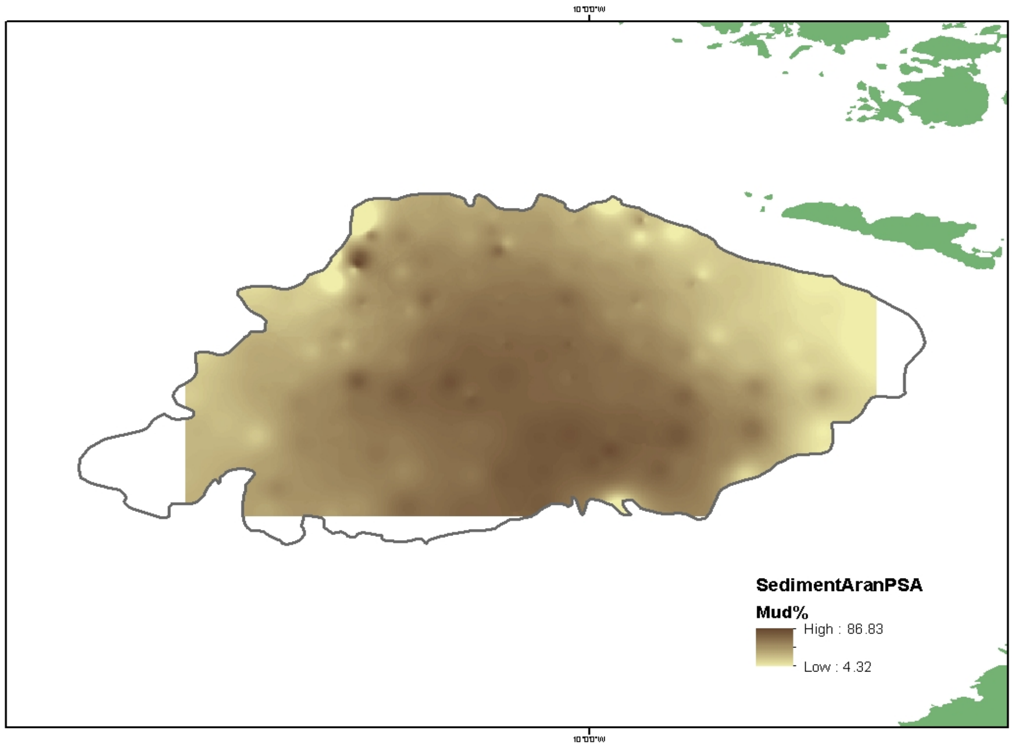


Figure 8.1.3. *Nephrops* in FU17. Sediment map of the Aran grounds showing % mud from particle size analysis of samples.

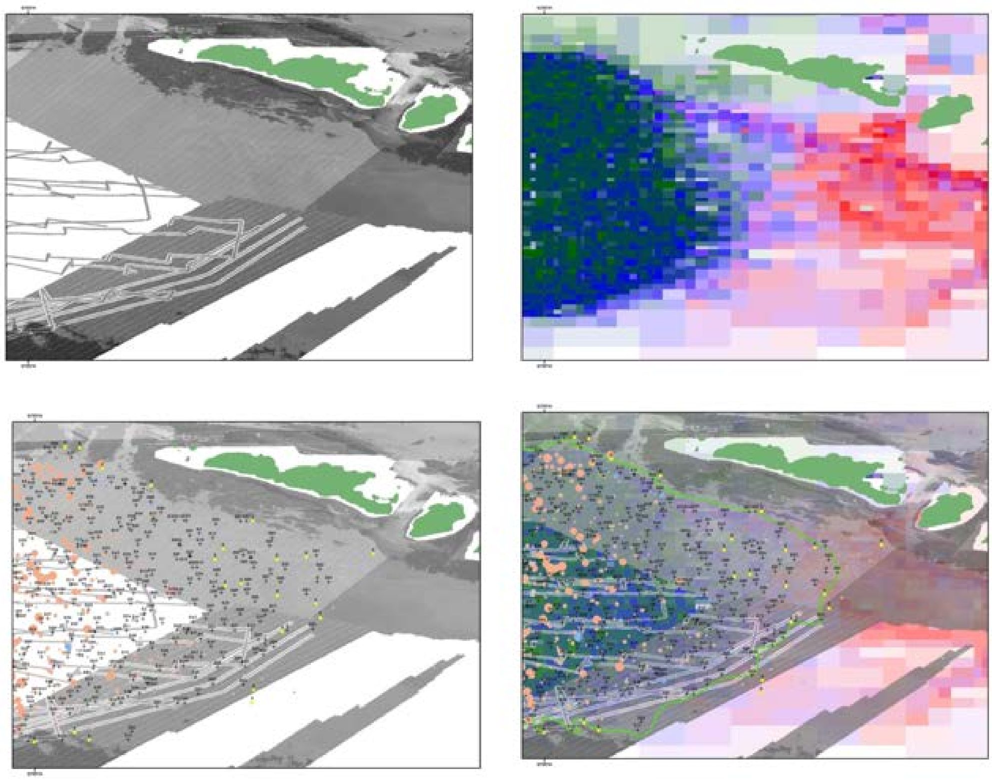


Figure 8.1.4. ***Nephrops*** **in FU17. Aran Grounds eastern edge. Top left panel: available backscatter data. Top right panel: integrated VMS data (red=0%** ***Nephrops*****; blue=50–60%** ***Nephrops*****). Bottom left panel: GFS (blue) and Observer cpue data (orange), UWTV stations (crosses) and zero density TV stations (yellow) overlaid on backscatter image. Bottom right panel: Revised polygon (green line) and all data mapped.**

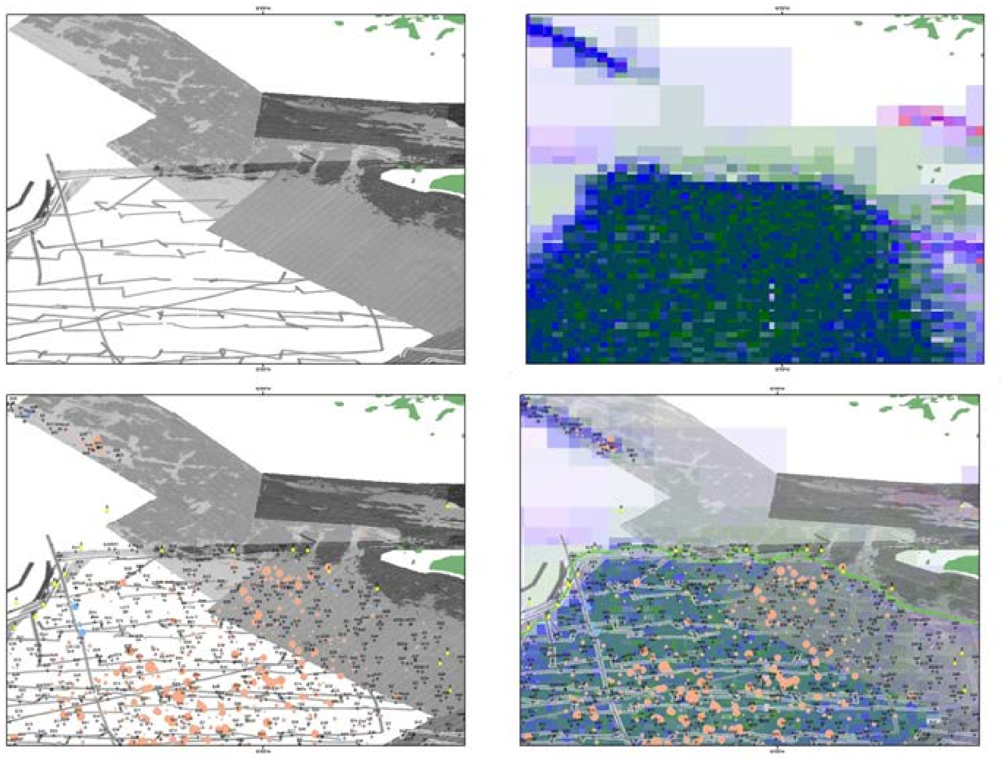


Figure 8.1.5. ***Nephrops*** **in FU17. Aran Grounds northern edge. Top left panel: available backscatter data. Top right panel: integrated VMS data. Bottom left panel: GFS (blue) and Observer cpue data (orange), UWTV stations (crosses) and zero density TV stations (yellow) overlaid on backscatter image. Bottom right panel: Revised polygon (green line) and all data.**

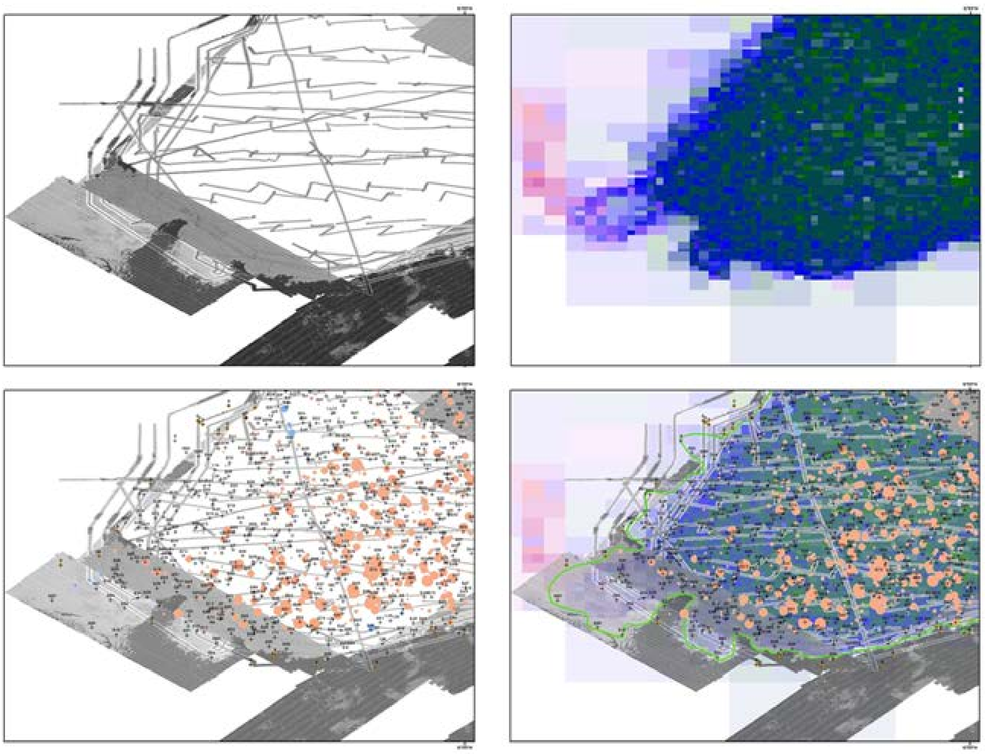


Figure 8.1.6. *Nephrops* in FU17. Aran Grounds southwestern edge. Top left panel: available backscatter data. Top right panel: integrated VMS data. Bottom left panel: GFS (blue) and Observer cpue data (orange), UWTV stations (crosses) and zero density TV stations (yellow) overlaid on backscatter image. Bottom right panel: Revised polygon (green line) and all data.

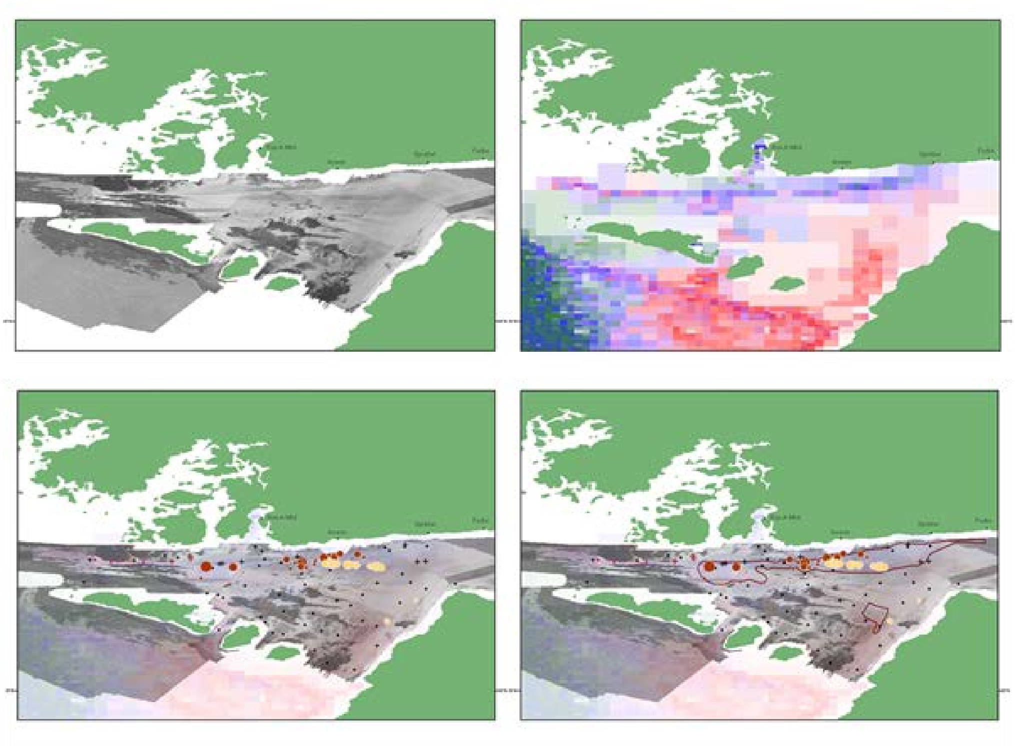


Figure 8.1.7. ***Nephrops*** **in FU17. Galway Bay. Top left panel: available backscatter data. Top right panel: integrated VMS data. Bottom left panel: GFS (brown) and Observer cpue data (orange), UWTV stations (crosses), zero density TV stations (yellow) and sediment data stations (dark circles) overlaid on backscatter image. Bottom right panel: Revised polygon (brown line) and all data.**

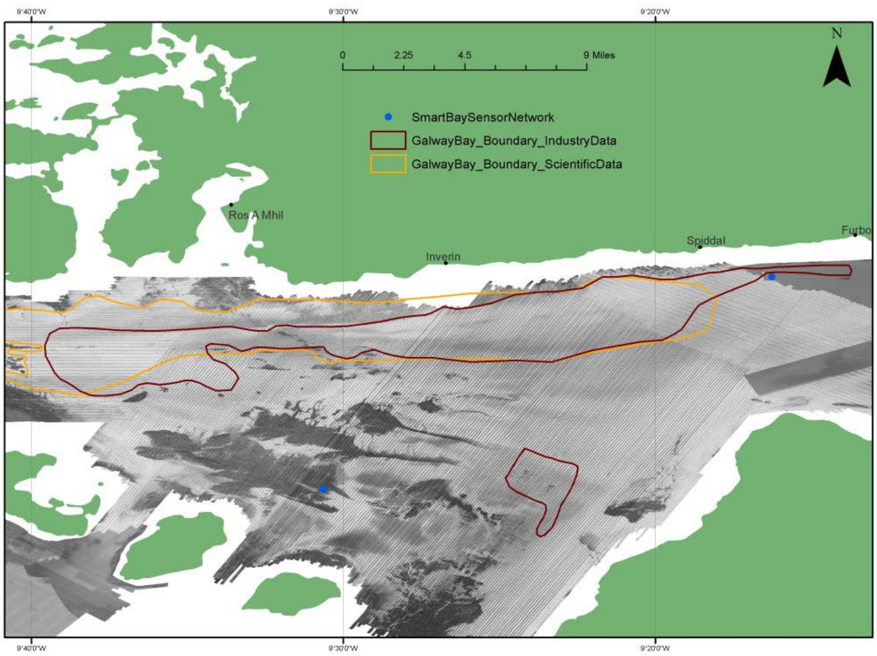


Figure 8.1.8. ***Nephrops*** **in FU17. Galway Bay. Industry and scientific boundary.**

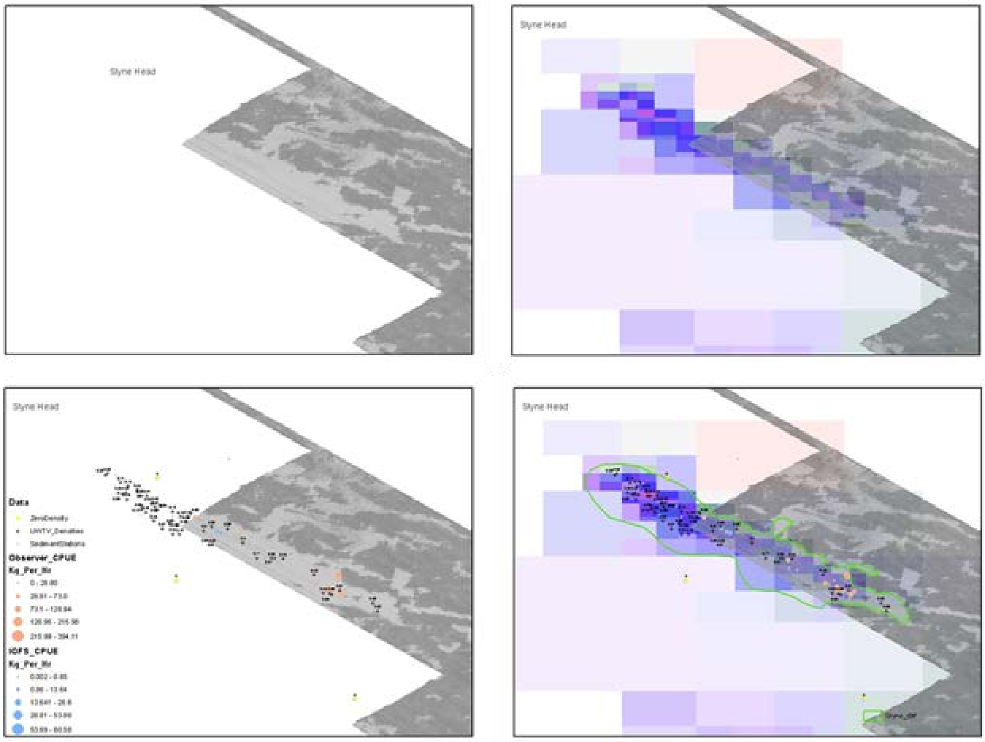


Figure 8.1.9. ***Nephrops*** **in FU17. Slyne Head. Top left panel: available backscatter data. Top right panel: integrated VMS data. Bottom left panel: GFS (blue) and Observer cpue data (brown), UWTV stations (crosses), zero density TV stations (yellow) and sediment data stations (dark circles) overlaid on backscatter image. Bottom right panel: Revised polygon (brown line) and all data.**

Table 8.1.1. *Nephrops* in FU17. Data sources available to revise the ground boundaries.

	Commercial Data		Seabed Mapping Data			Survey Data	
Ground	VMS	Observer Trip Data	Backscatter	Sediment	UWTV	Sediment	IBTS GroundFish
	2006–2014	1996–2014	Various	Various	2002–2014	Various	2003–2014
Aran	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Galway Bay	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Slyne Head	Yes	Yes	Yes	No	Yes	Yes	Yes

Table 8.1.2. *Nephrops* in FU17. Area (km²) calculation for each ground by projection method in Arc GIS 10.

	ArcGIS10 Projections			
	Irish National Grid (km²)	Eckert VI (world) (km²)	Cylindrical Equal Area (km²)	Average (km²)
Aran	1202.99	1200.43	1202.64	1202.018
Galway Bay	79.03	78.87	79.02	78.975
Slyne Head	39.18	39.09	39.17	39.146

Table 8.1.3. *Nephrops* in FU17. Final areas (km²) by grounds.

	WGCSE 2006	IBP 2015
	Area (km²)	
Aran	940.00	1202.0
Galway Bay	41.00	79.0
Slyne Head	26.00	39.1
Total	1007.0	1320.1

Table 8.3.1. ***Nephrops*** **in FU17. Revisions to historical distance over ground calculations.**

Distance Over Ground (m)			
Survey Year	Aran IBP	Aran Original	% Change
2002	10,055.00	11,087.99	9%
2003	10,050.68	10,582.29	5%
2004	10,003.98	10,081.95	1%
2005	11,505.76	11,601.20	1%
2006	14,578.52	14,578.52	0%
2007	14,988.62	15,002.19	0%
2008	17,363.33	17,433.05	0%
2009	14,404.00	14,533.09	1%
2010	15,185.03	15,255.05	0%
2011	15,195.06	15,526.78	2%
2012	4,038.26	4,040.47	0%
2013	5,898.44	5,898.44	0%
2014	7,346.08	7,346.08	0%
Distance Over Ground (m)			
Survey Year	Galway Bay IBP	Galway Bay Original	% Change
2002	1,646.33	1,665.35	1%
2003	749.43	757.00	1%
2004	1,437.43	1,465.86	2%
2005	590.78	590.78	0%
2006	719.62	719.62	0%
2007	1,135.79	1,135.79	0%
2008	2,214.82	2,225.79	0%
2009	1,607.05	1,609.32	0%
2010	1,710.09	1,712.00	0%
2011	1,804.60	1,804.60	0%
2012	613.67	613.67	0%
2013	1,101.62	1,101.62	0%
2014	754.98	754.98	0%

	Distance Over Ground (m)		
Survey Year	Slyne Head IBP	Slyne Head Original	% Change
2002	1,390.83	1,404.90	1%
2003	na	na	na
2004	638.53	672.91	5%
2005	450.49	450.49	0%
2006	727.58	727.58	0%
2007	1,061.91	1,061.91	0%
2008	na	na	na
2009	708.22	708.22	0%
2010	1,489.83	1,489.83	0%
2011	1,554.84	1,554.84	0%
2012	540.18	540.18	0%
2013	811.75	811.75	0%
2014	829.11	829.11	0%

na- survey data not available.

9 Review of abundance estimates

9.1 Kriging analysis of the Aran Grounds

As part of the IBP process the full krigging procedure for the Aran ground from 2002 to 2015 was reviewed and fully documented through an r markdown document (Lordan, WD1). The new ground boundary has been used to calculate the abundance for each *Nephrops* patch. The geostatistical analysis was carried out using RGeostats package (Renard D. *et al.*, 2015). The steps are; construction of experimental variogram, a model variogram □(*h*), was produced with an exponential model (see below), create krigged grid file using all datapoints as neighbours, IBPNeph boundary used to estimate the domain area, mean density, total burrow abundance and finally calculate survey precision. The main results of this analysis are shown here. Figure 9.1.1 shows the densities have fluctuated considerably over the time-series and throughout the Aran grounds. The Galway Bay estimates fluctuate widely but appear to be highly correlated with the Aran ground (except 2004). Estimates for the Slyne Head ground also fluctuate considerably but show no significant correlation with the other areas (Figure 9.1.2). Table 9.1.1 shows the Aran ground abundance estimates and CV (or relative standard error) which is well below (<6%) the recommendation of 20% by SGNeps (ICES, 2009). The CVs on the abundance estimates for Galway Bay and Slyne Head are also well within the SGNeps recommendation showing the surveys are precise (Doyle *et al.*, 2015). Figure 9.1.3 and Table 9.1.2 shows the total abundance estimate for FU17 with the IBPNeph proposed MSY $B_{trigger.}$

9.2 MSY $B_{trigger}$

MSY $B_{trigger}$ is intended to safeguard against an undesirable or unexpected low SSB when fishing at F_{MSY} and is considered the lower bound of SSB fluctuations around B_{MSY}. For *Nephrops* stocks MSY $B_{trigger}$ has been defined as the lowest stock size from which the abundance has increased. Accordingly with this definition $B_{trigger}$ is set for FU17 as 540 million, corresponded to the abundance observed in 2008 rounded to the nearest 10 (Figure 9.2.1).

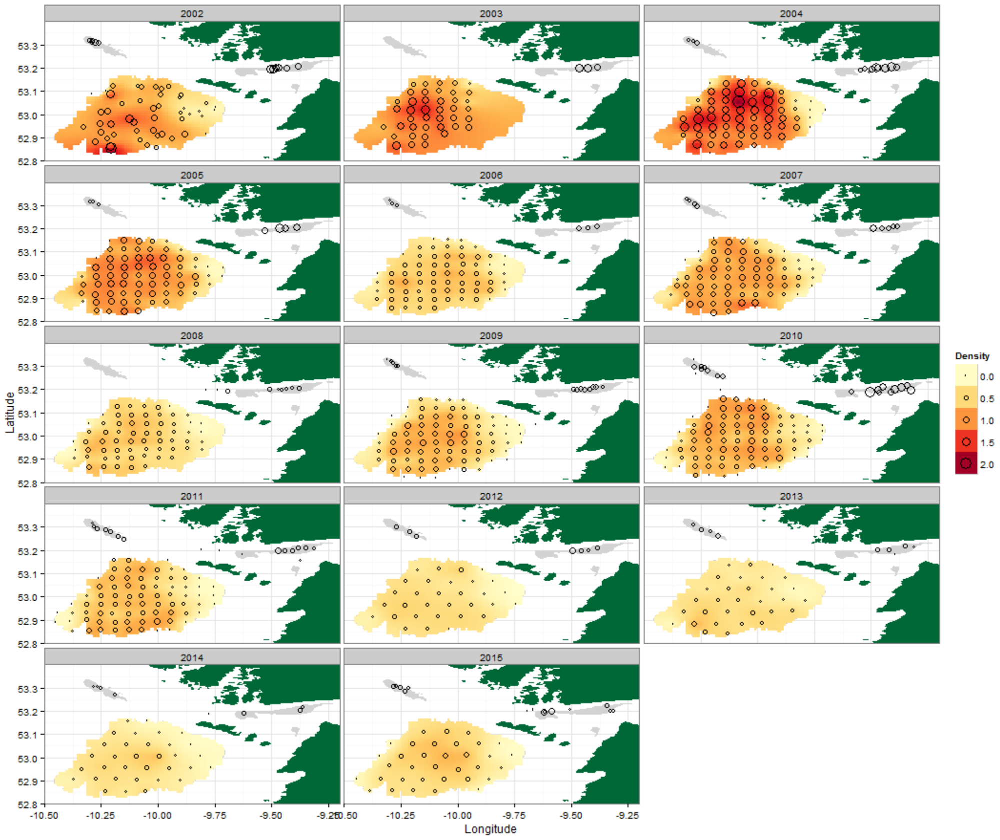


Figure 9.1.1. Contour plots of the krigged density estimates by year from 2002 (top left)–2015 (bottom left).

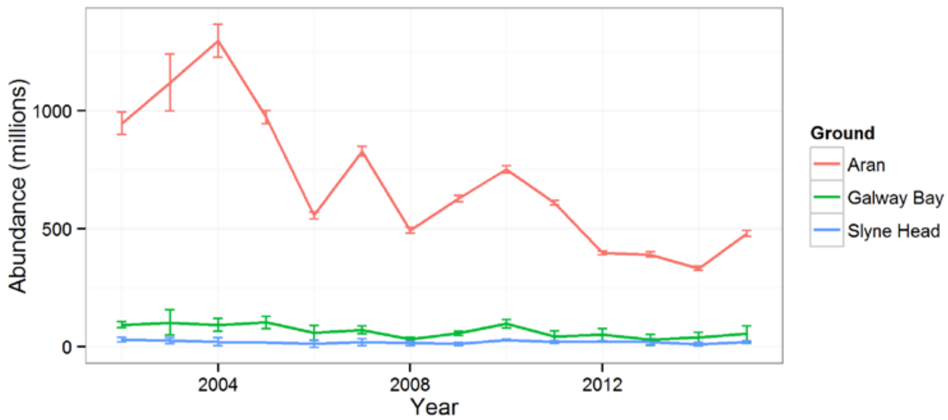


Figure 9.1.2. Time-series of abundance estimates for the Aran Grounds, Galway Bay and Slyne Head (error bars indicate 95% confidence intervals).

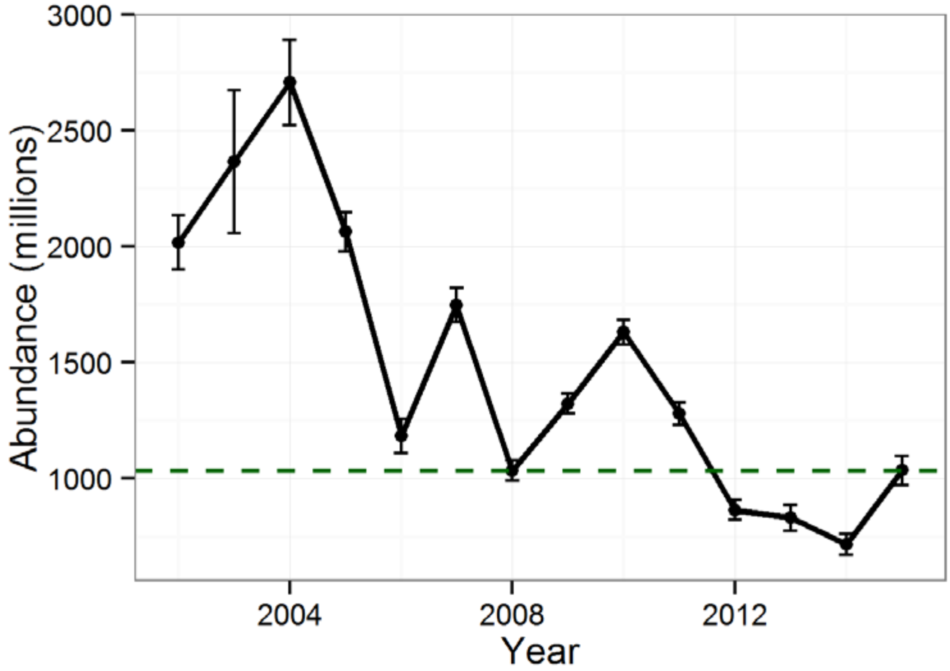


Figure 9.2.1. Time-series of total abundance estimates for FU17 (error bars indicate 95% confidence intervals) and $B_{trigger}$ is dashed green line.

Table 9.1.1. Overview Aran of geostatistical results from 2002–2015.

FU	Ground	Year	Number of Stations	Mean Density (burrows/m²)	Estimation Standard Deviation	Area (km²)	Geostatistical abundance estimate (millions of Burrows)	CV on Burrow estimate
17	Aran	2002	49	0.79	0.17	1196	947	3%
		2003	41	0.94	0.09	1196	1118	6%
		2004	64	1.08	0.27	1196	1297	3%
		2005	70	0.81	0.12	1196	972	2%
		2006	67	0.46	0.06	1196	556	3%
		2007	71	0.69	0.12	1196	828	2%
		2008	63	0.41	0.05	1196	494	3%
		2009	82	0.52	0.10	1196	627	2%
		2010	87	0.63	0.10	1196	752	2%
		2011	76	0.51	0.09	1196	609	2%
		2012	31*	0.33	0.03	1196	397	3%
		2013	31*	0.33	0.03	1196	390	4%
		2014	33*	0.28	0.03	1196	332	4%
		2015	34*	0.40	0.06	1197	480	4%

*** reduced isometric grid.**

Table 9.1.2. Total abundance estimate for FU17 N*ephrops* (Aran, Galway Bay and Slyne Head patch) 2002–2015.

Year	Abundance (Millions)	Upper bound	Lower bound
2002	1069.796	1139.209	1000.383
2003	1246.37	1432.821	1059.92
2004	1409.782	1523.114	1296.45
2005	1091.971	1148.121	1035.822
2006	626.7601	686.7448	566.7755
2007	919.7013	972.1887	867.214
2008	541.1782	572.2073	510.1491
2009	695.6454	724.5324	666.7583
2010	878.5592	916.5185	840.5999
2011	672.1959	710.8391	633.5526
2012	468.2692	504.6183	431.92
2013	441.0297	486.5642	395.4952
2014	383.0244	419.5843	346.4646
2015	555.5154	605.8891	505.1418

10 Review of FU17 stock parameters

10.1 Review Mean Length/Weight for landings and discards

As part of the IBP process the national sample raising procedures for FU17 were reviewed and fully documented through an r markdown document (Lordan, WD2). The main results of this analysis are shown here. Up to now unsorted catch samples were partitioned into landings and discards using a quarterly on-board retention ogive. During the review it became apparent that the number of quarterly samples was insufficient to derive quarterly ogives. In practice a number of *ad hoc* fill-ins were often made to solve this problem. Furthermore Figure 10.1 illustrates that while there have been significant changes in the retention ogives over the recent few years there is no evidence that there are consistent quarterly differences. **The IBP concluded that annual discard ogives should be used instead of quarterly ones in the raising.** These are applied to quarterly length distributions and raised to total quarterly landings before aggregation. A further raising procedure is applied to raise the annual sampled Irish data to international landings (this also addresses quarters with missing length samples).

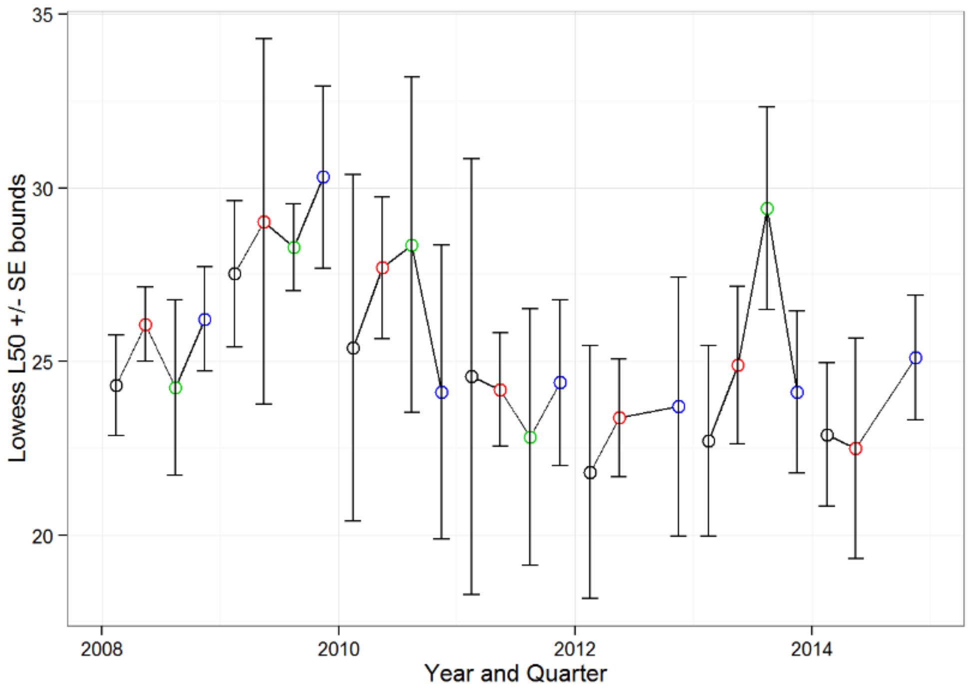


Figure 10.1. The quarterly estimated L_{50} with standard error bounds for the on-board retention ogives for samples from the Aran grounds.

10.2 Mean weight

Annual mean weight in the landings is calculated from the length–frequency data and Pope and Thomas (1955) length–weight relationship. Figure 10.2 shows the mean weight by sex for Aran grounds over the time. Explorations of the mean weight in the catch samples by sex displayed a strong cyclical pattern in the females. This corresponds to the emergence of mature females from the burrows to mate in summer. There are also some indications of cyclical patterns for the males. This implies that the sampling design should take into account a temporal stratification probably at a monthly scale.

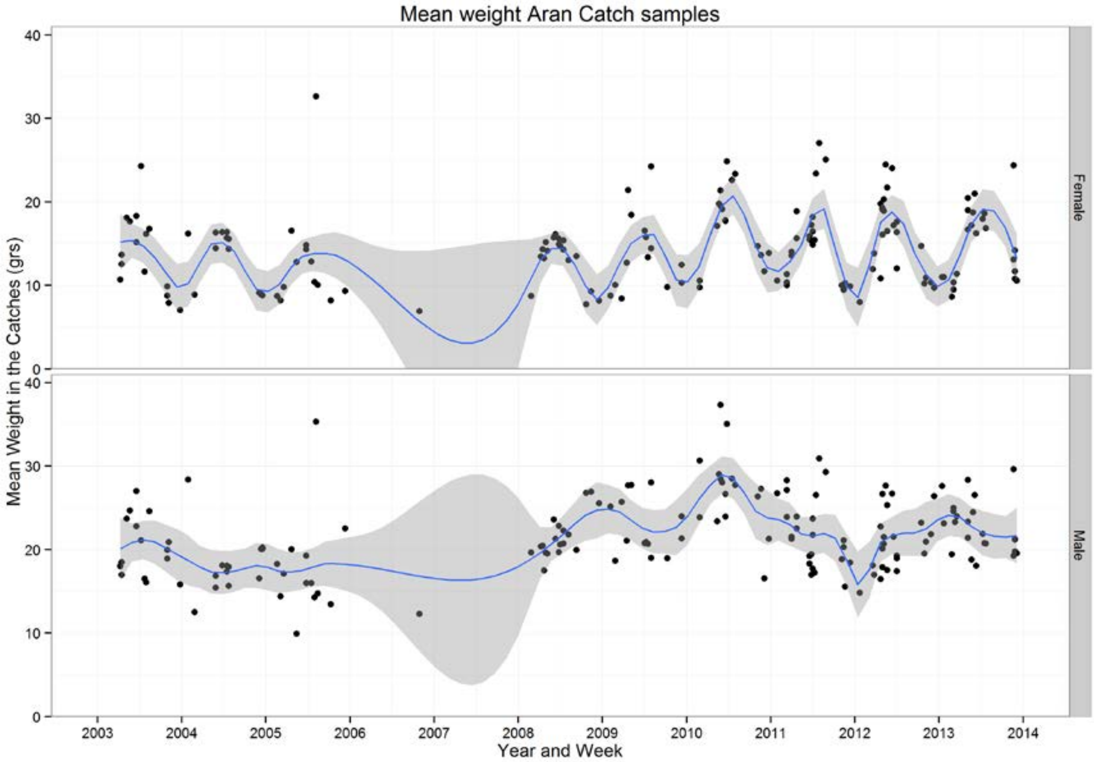


Figure 10.2. Mean weights (grs) for male and females from catch samples.

10.3 Review of sex ratio from Catch samples

Previous *Nephrops* working groups have highlighted stability in sex ratio as an important indicator for *Nephrops* stocks. As for mean weight a cyclical pattern is evident which is linked to female emergence behaviour (Figure 10.3).

IBPNeph recommend that sex ratio indicators be updated and reviewed annually by WGCSE.

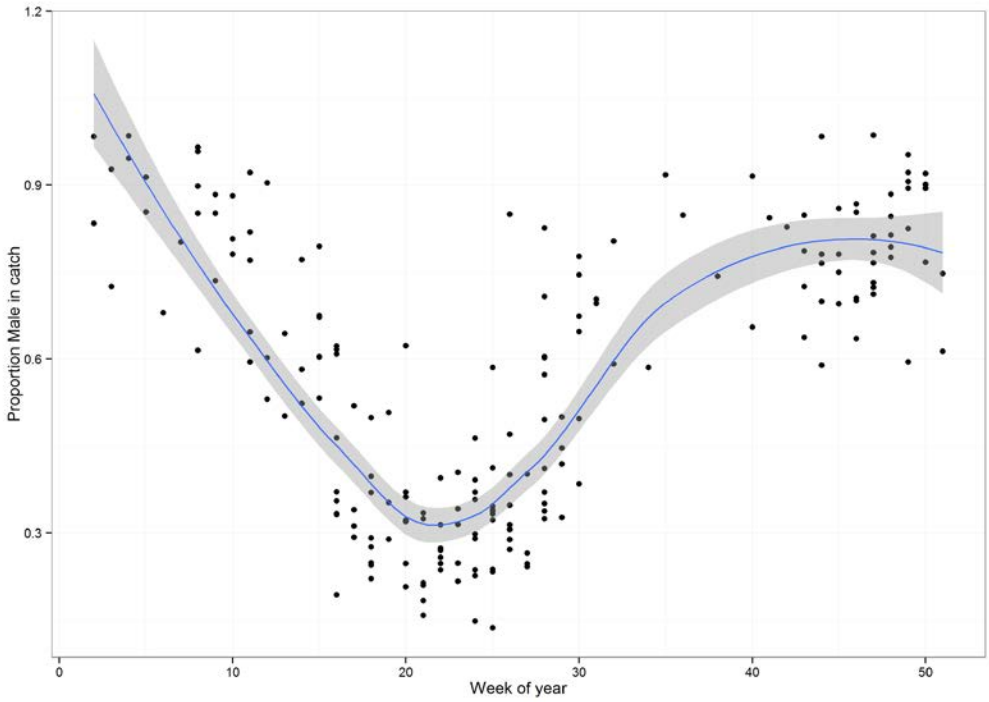


Figure 10.3. Proportion of males in the catch samples by week.

10.4 Review of maturity

Maturity data for females have been recorded during the *Nephrops* catch sampling programme, by month and year and the maturity stage of females is recorded based on a visual examination of the gonads. The size at which 50% of the female animals were mature (L_{50}) was investigated for the Aran grounds based on data from 2008 months pooled by month. June to August was selected based on maturity schedules observed (Figure 10.4.1).This gives L_{50} of 21 mm CL for females (Figure 10.4.2). This is not significantly different from previous L_{50} estimate of 22 mm CL (ICES, 2006).

IBPNeph concluded that L_{50} of 22 mm CL is appropriate to Aran Grounds.

No update to male maturity was made at IBPNeph and the same L_{50} should be assumed for males. Estimation of male maturity using a segmented regression model fitted to a scatterplot of carapace vs. appendix masculine length was proposed by McQuaid *et al*., 2006 and ICES (2006). This approach has been examined for other FUs around Ireland and is known to be sensitive to outliers. The biological significance of the observed breakpoint is not known since males are mature at smaller size but may not be able to functionally mate. The assumption that males mature at the same CL as females may well be reasonably accurate. Ultimately this only impacts on the calculation of the SPR male component and will not impact on the $F_{0.1}$ a harvest rate for this stock.

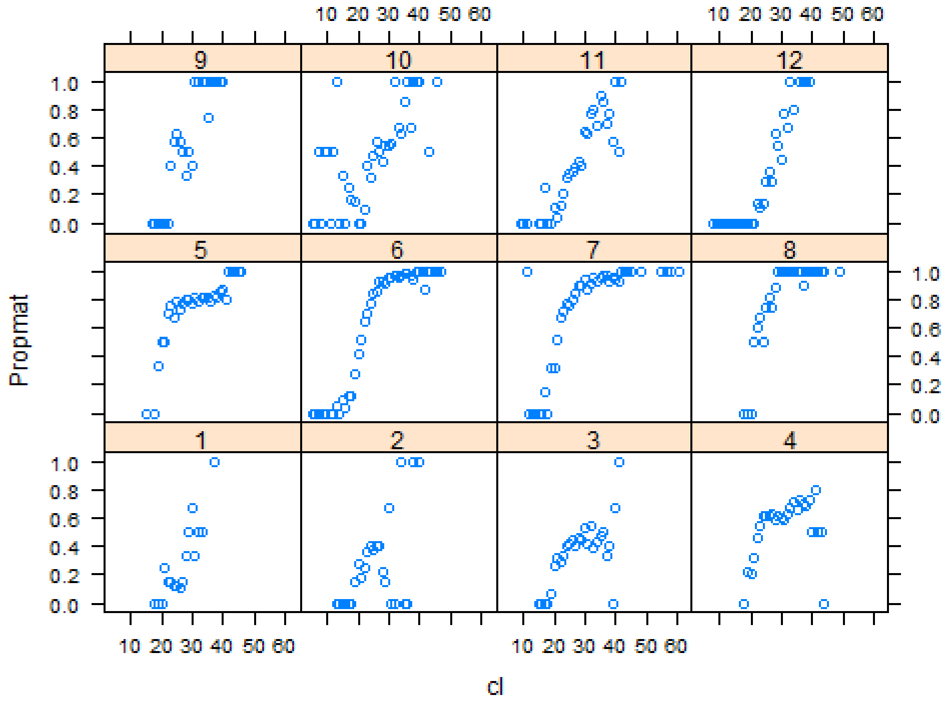


Figure 10.4.1 Proportion of female mature by month pooled for years 2008–2014.

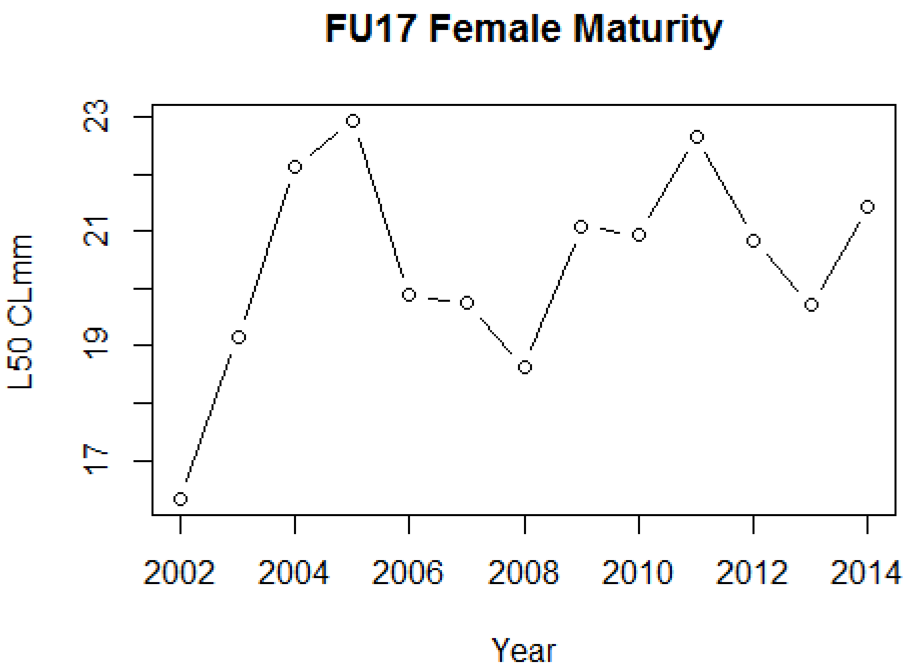


Figure 10.4.2. L_{50} of mature females for selected months June–August by year.

10.5 Discard selection survival rate

Currently there are no direct survivability studies available for this area. Given the trip durations (~five days average) and behaviour of the fleet the majority of discards on the Aran Grounds are returned to the sea over suitable sediment. The proportion scavenged by birds is probably quite low. Prior to 2015 a discard survival rate of 10% was used because density of *Nephrops* on the seabed was high.

Because density has declined to medium it was decided to increase the discard survival assumption to 25% to be consistent with other medium density grounds in VII and VIa. IBPNeph recommended that this parameter should be revised if any survivability experiments take place in the Aran grounds. IBPNeph recommended that exploratory analysis should be done in a future benchmark regarding sensitivity analysis and how these parameters influence the SCA outputs.

10.6 Review of effort and lpue data

As part of the IBP the FU17 logbook information was thoroughly reviewed and presented to the fishing industry. The industries perception was that effort has significantly reduced on the Aran grounds. This review showed that while effort in hours and days showed no trend since 1995 that there was trend in effort when measured in kilowatt days (Figure 10.6.1). The number of vessels involved in the fishery has been relatively stable over time (Figure 10.6.2).

There have been also changes in fleet structure (Figure 10.6.3) over time. At the start of the time-series vessel power was normally distributed around a mean of ~175kw. Towards the end of the time-series the power frequency distribution has become increasingly bi-modal with the majority of vessels in the larger power mode which centres on 250 kws. The mean and modal power show increasing trends overtime.

The behaviour of the fleet has also changed significantly since 1995 (Figure 10.6.4). The so called DNA plot shows the daily landings by individual vessels as reported in logbooks. In the past individual vessels exhibited a behaviour where the spent long periods of time on the Aran grounds. Some vessels appeared to be fishing on a continuous basis throughout the year. In the last few years the fishery has become significantly more concentrated in time. Vessels only fish the ground for short periods and record higher daily landings. This change in behaviour reflects a generally more mobile behaviour by *Nephrops* targeting vessels which switch between grounds as the "prawns come on".

The efficiency of vessels has improved significantly since 1995 with increased twin rigs initially and now quad rigs since 2012. Net designs and on-board technology have also improved dramatically. These factors are not well documented in a way that can be readily used to standardise and lpue time-series. IBPNeph concluded that effort should be reported in the WGCSE report in KWdays. Lpue should be reported in KG/kwdays in the knowledge that the trend is likely to be a biased underestimate because it is not adjusted for efficiency or behavioural changes.

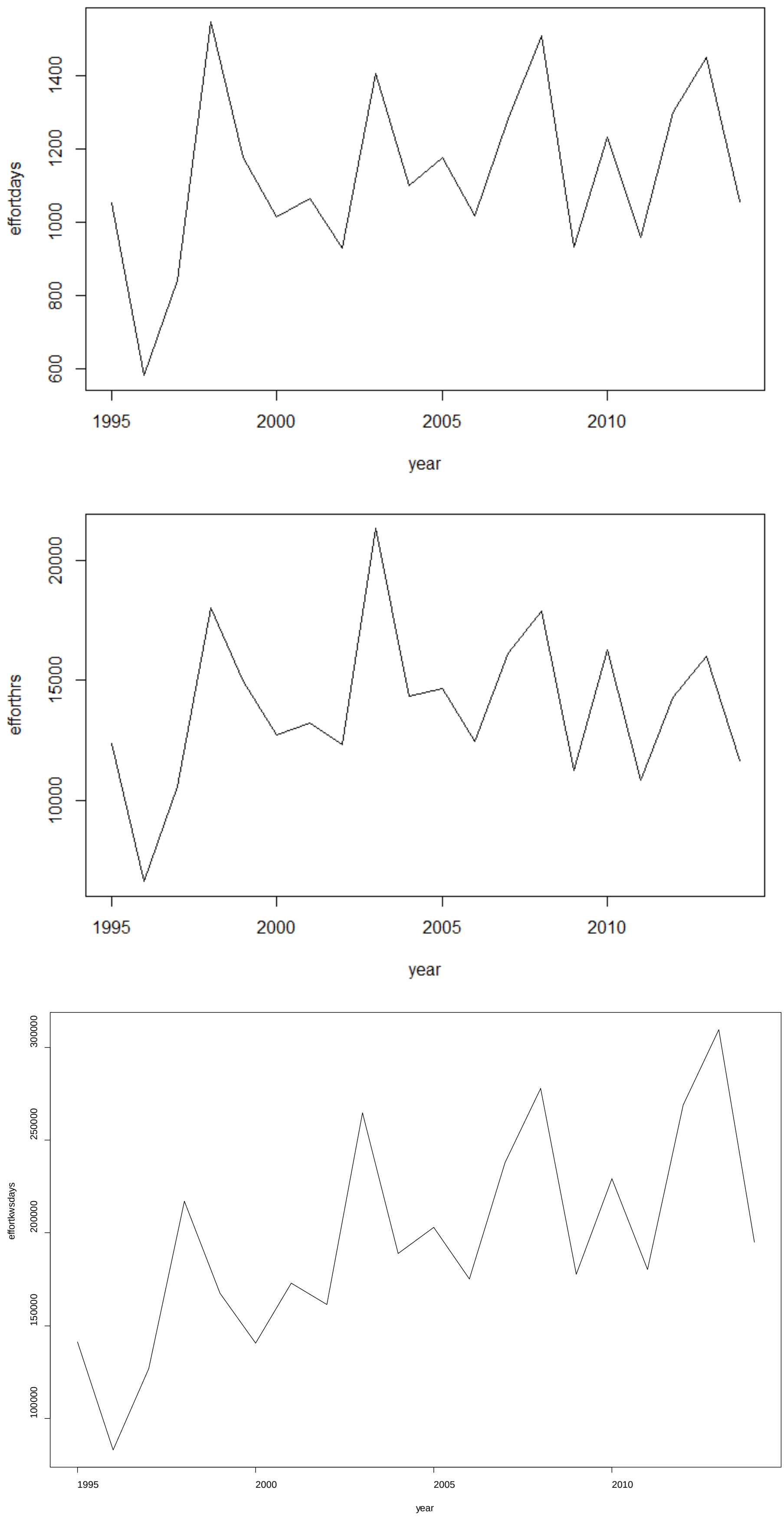


Figure 10.6.1. Effort trends using various different metrics (Top panel days, middle hours fished and bottom kilowatt days).

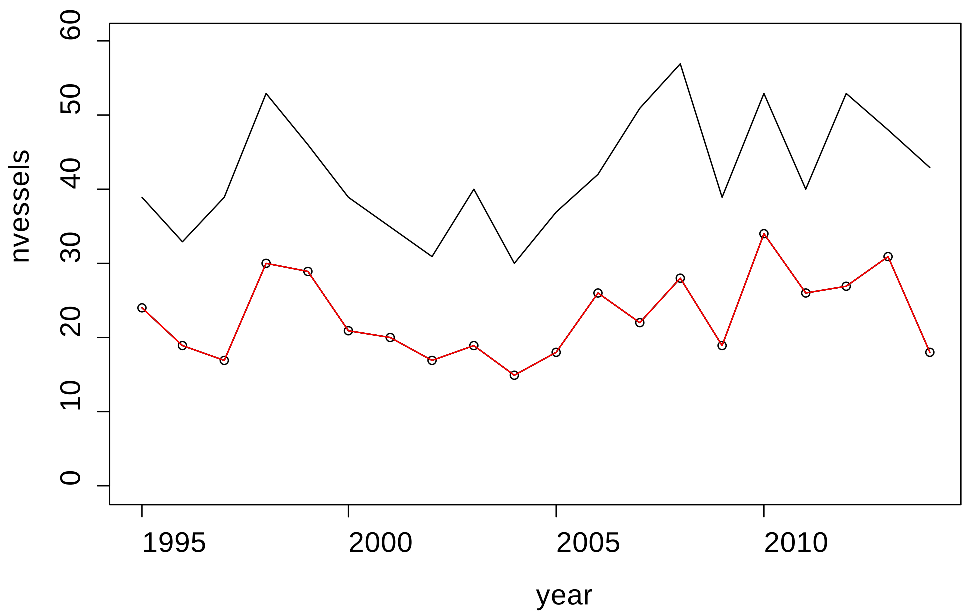


Figure 10.6.2. Number of vessels fishing on the Aran Grounds by year (red line landings >10 t threshold, black line all vessels).

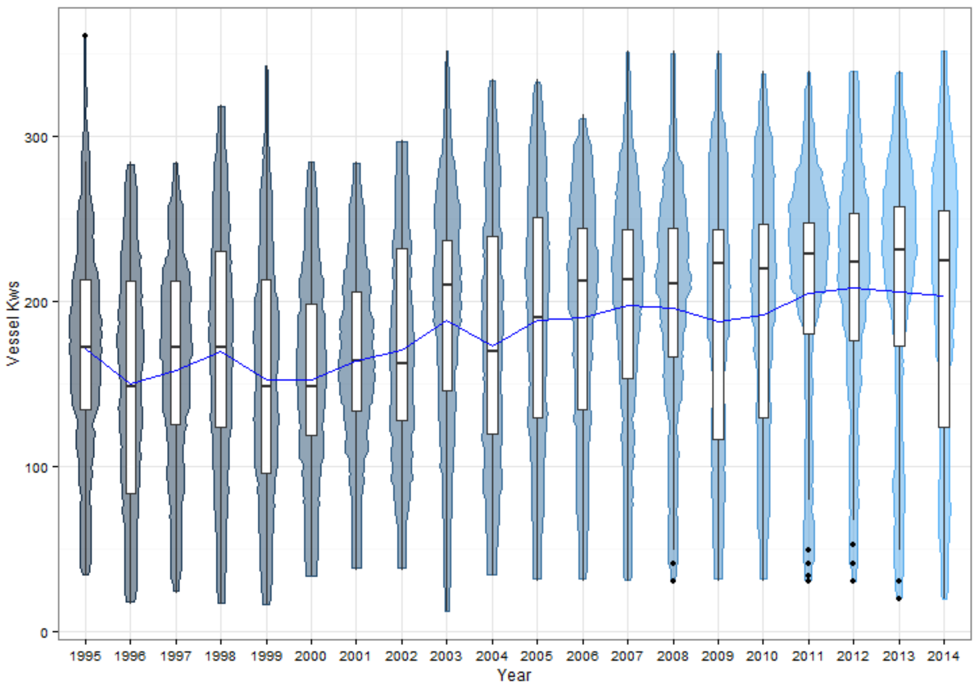


Figure 10.6.3. Combined box and kite plot of vessel power on the Aran Grounds by year. The blue line indicates the mean.

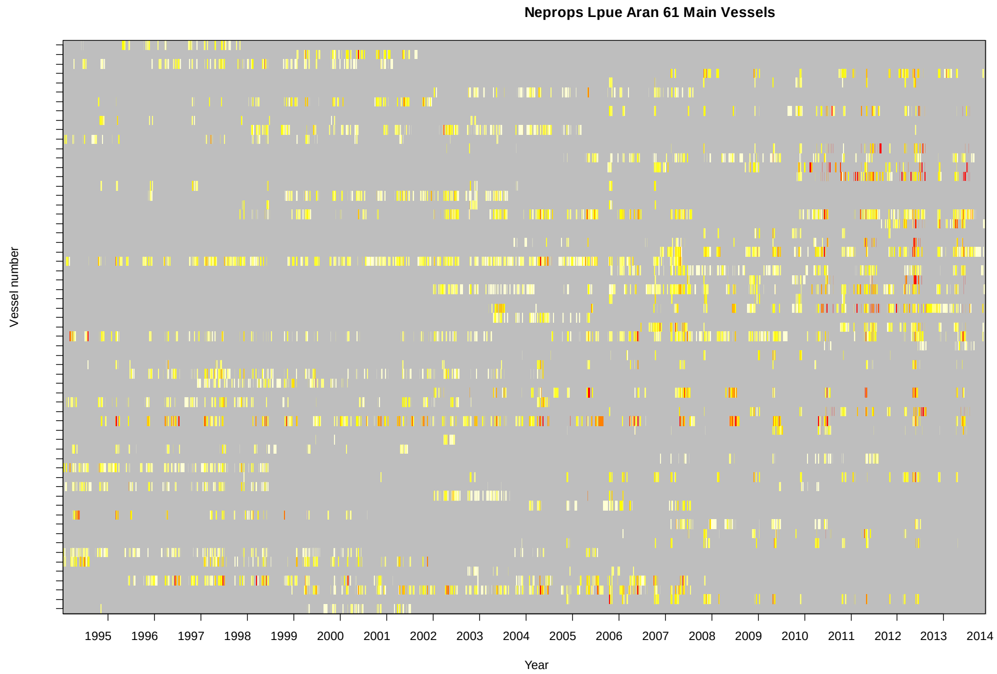


Figure 10.6.4. DNA plot of vessel landings by day over time for the Aran grounds.

11 Review of FU17 Reference Points

New MSY explorations were carried out at the current IBP for FU17. A SCA (separable cohort analysis, model Bell) was used to estimate sustainable stock-specific Harvest Ratio reference points. The input data, code and output diagnostics are available in the IBP SharePoint site. All settings used were the same as previous with the exception of the discard survival percentage.

Most of the setting and initial parameters were as previously documented in the stock annex.

Discard survival: **25%**

FemMature<-c(22,23) L_{25}/L_{50} for female maturity.

MalMature<-c(22,23) L_{25}/L_{50} for male maturity.

n.indivs<-c(430) TV survey index: three year average reference period 2013–2015.

surv.time<-c(0.66) Fraction of year surveys occurs.

TV.sel<-c(16.5,17) TV selectivity.

alpha<-0.001 Survey weighting: 0.001 (low).

f.range<-c(0, 0.01, seq(0.05, 4, 0.05)) F.range for estimating the Yield-per-recruit.

discard.weight<-c(1) discard weighting.

The model also has five initial parameters to estimate:

1) Initial population size at the smallest length class equal sex distribution assumed.
2) Length at 25% selection.
3) Multiplier on L_{25} to give L_{50}.
4) Fishing mortalities at full selection for males and immature females.
5) Fishing mortality at full selection for mature females.

initial.parameters <- c(1.5,21.5, 1.15,0.4,0.3).

Additional parameters required such as the von Bertalanffy growth parameters, natural mortality and weight–length parameters by sex are required. These parameters are given in Table 11.1 below.

Table 11.1. Input parameters for FU17 SCA.

Parameter	Males	Immature Females	Mature females
L_∞	60	60	56
K	0.16	0.16	0.08
Natural Mortality	0.3	0.3	0.2
Discard Survival	25%	25%	25%
A	0.000322	0.000684	0.000684
B	3.207	2.963	2.963

The SCA model was fitted to a moving three year window of average length–frequency distributions. The results are shown in Table 11.2 below and model fits are shown in Figures 11.1–11.5. The fits were reasonable to the three average LFDs since 2012.

Table 11.2. A summary of the SCA reference point estimates for different average length–frequency distribution three year averaging windows.

REF POINT	2012–2014	2011–2013	2010–2012	2009–2011*	2008–2010*	AVERAGE
HR0.1.Male	7.7	8.8	8.7	7.6	7.6	8.08
HR0.1.Female	10.1	10.4	9.6	10	10	10.02
HR0.1.Comb	8.5	9.6	8.7	8.5	8.4	8.74
HRmax.Male	14.1	15.2	15	12.7	12.7	13.94
HRmax.Female	20.1	19.5	18.2	17.6	16.7	18.42
HRmax.Comb	16.3	16.3	16.1	14.5	14	15.44
HR35.Male	11.6	11.9	11.8	10.8	10.7	11.36
HR35.Female	12.2	12.6	14.4	15.6	15.7	14.1
HR35.Comb	12.2	12.6	13.2	12.7	13.4	12.82

*** Fits of SCA model not great.**

IBPNEPH concluded that the most recent length–frequency distributions were the most reflective of the selection and size distributions in the fishery. Because of the following factors:

- The observed burrow density has declined from high (>0.8 individuals/m^2) at the start of the series to medium density (~0.3 individuals/m^2) towards the end of the time-series.
- The nature of the fishery has also changed from a continuous fishery throughout the year to a fishery which is more concentrated on periods of high catch rates.

A harvest ratio consistent with a combined sex $F_{0.1}$ is considered an appropriate proxy for F_{MSY}. The $F_{0.1}$ estimate from the 2012–2014 is proposed as the best value to use since there is a trend in the sex-ratio within the catches, therefore the model fit to the most recent data gives the most representative impression of current fishery practice.

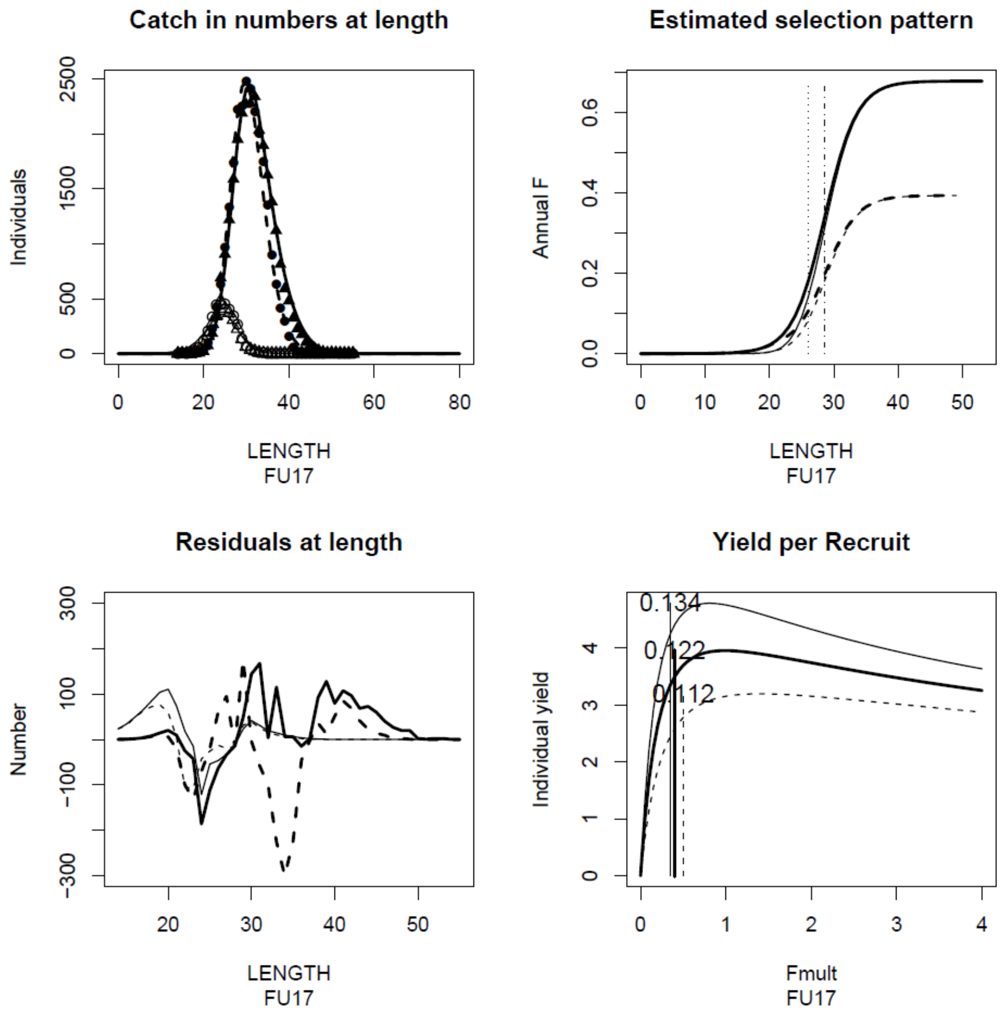
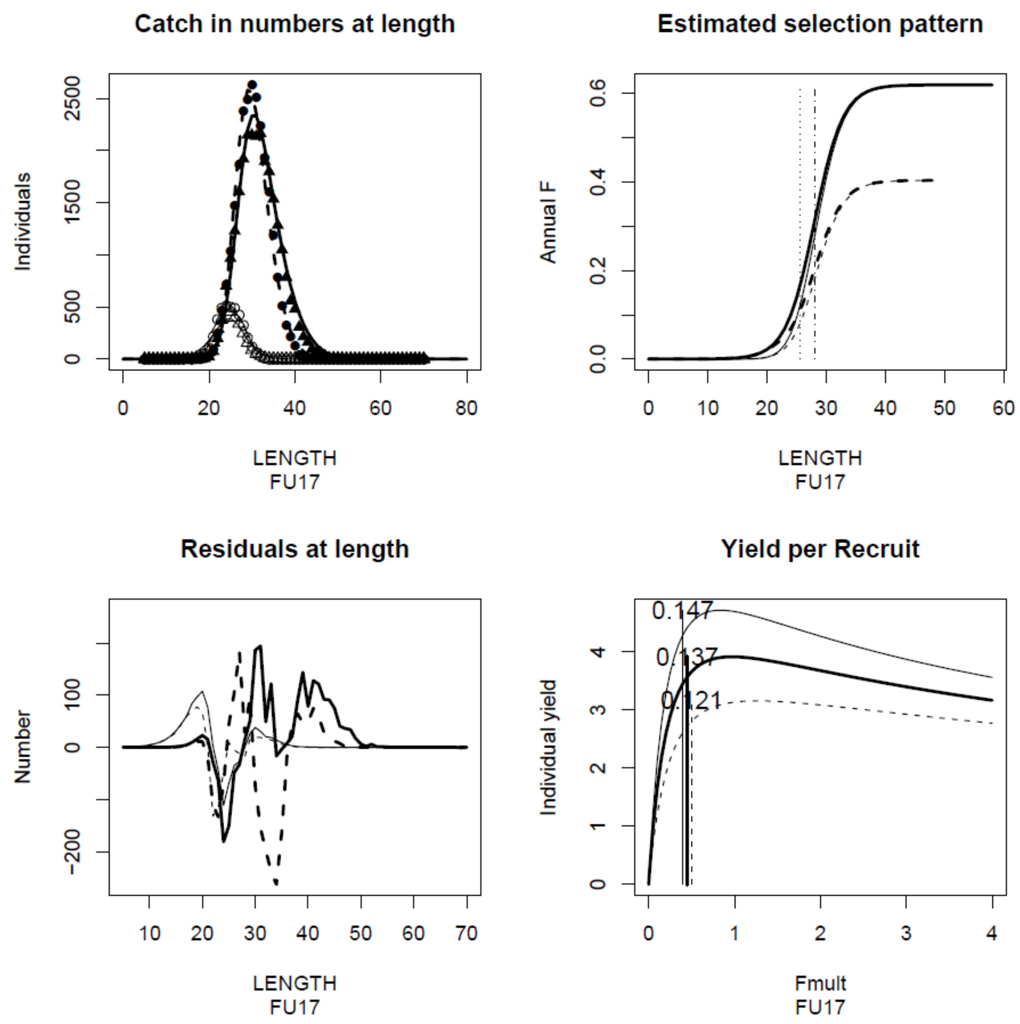


Figure 11.1. Aran grounds (FU17): Separable Cohort analysis (SCA) model fit to average length–frequency distributions 2012–2014. Solid lines are for males, dashed lines are females, thick lines represent the landings component, and the thin lines represent the discarded component. The top left panel gives observed and predicted numbers-at-length in the discards and landings, top right gives the fishing mortality-at-length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed–expected) at length. The bottom right gives the Yield-per-recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.



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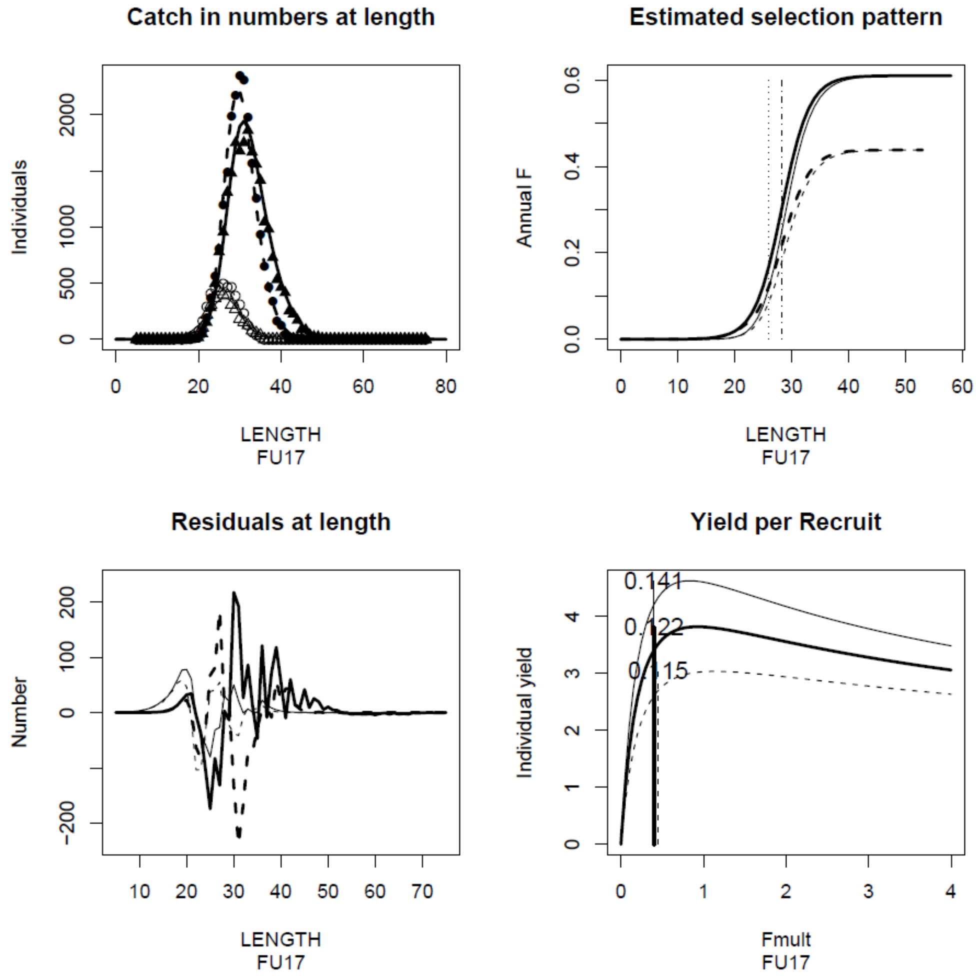

Figure 11.3. Aran grounds (FU17): Separable Cohort analysis (SCA) model fit to average length–frequency distributions 2010–2012. Solid lines are for males, dashed lines are females, thick lines represent the landings component, and the thin lines represent the discarded component. The top left panel gives observed and predicted numbers-at-length in the discards and landings, top right gives the fishing mortality-at-length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed–expected) at length. The bottom right gives the Yield-per-recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.

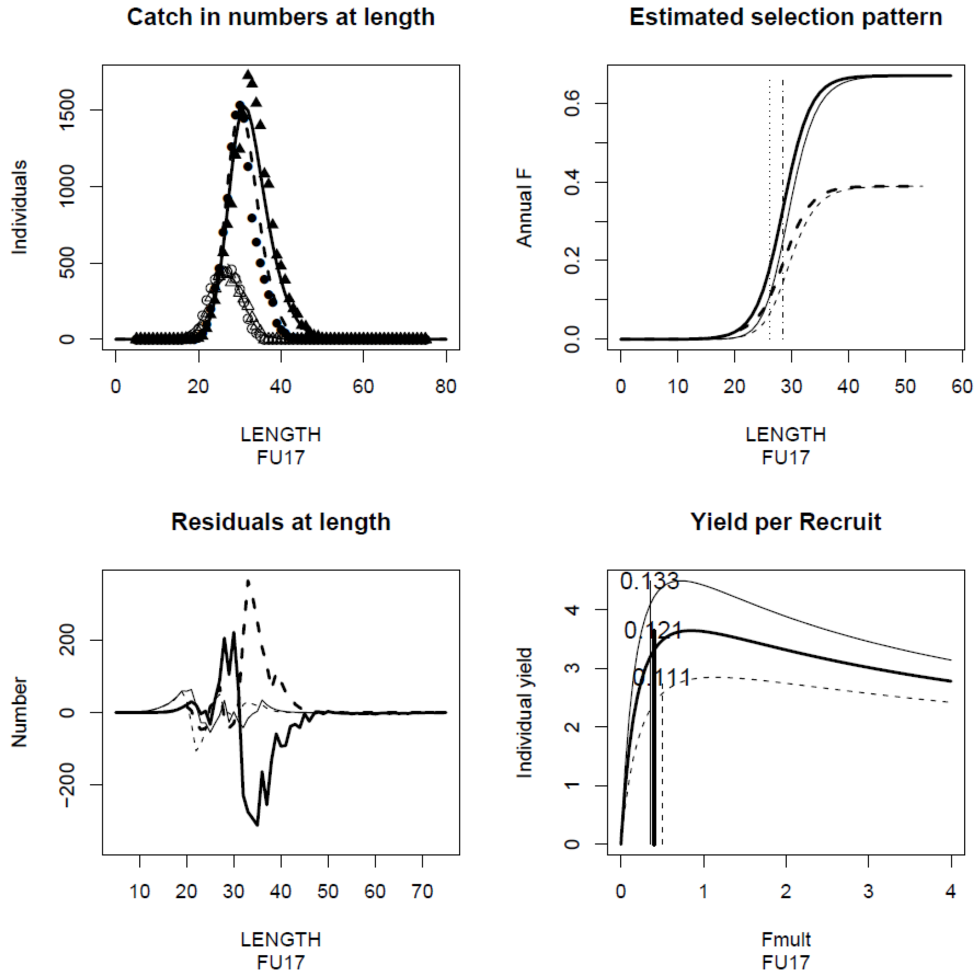

Figure 11.4. Aran grounds (FU17): Separable Cohort analysis (SCA) model fit to average length–frequency distributions 2009–2011. Solid lines are for males, dashed lines are females, thick lines represent the landings component, and the thin lines represent the discarded component. The top left panel gives observed and predicted numbers-at-length in the discards and landings, top right gives the fishing mortality-at-length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed–expected) at length. The bottom right gives the Yield-per-recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.

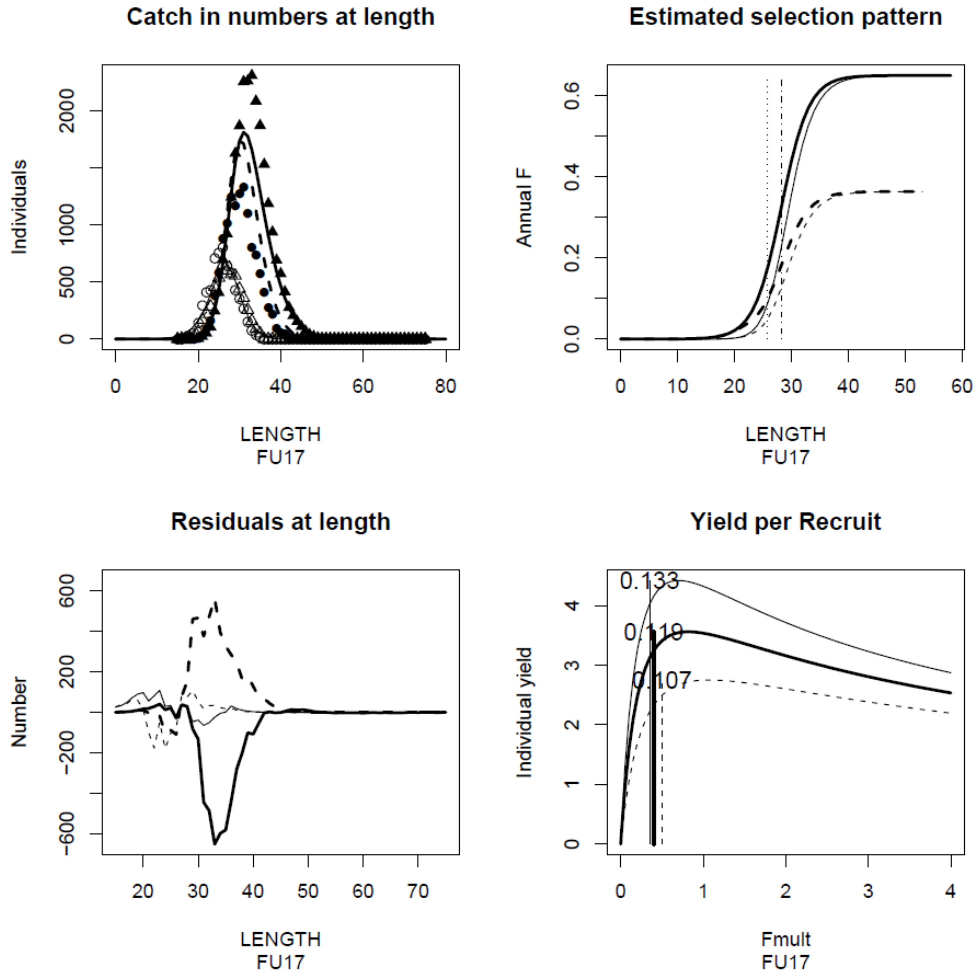

Figure 11.5. Aran grounds (FU17): Separable Cohort analysis (SCA) model fit to average length–frequency distributions 2008–2010. Solid lines are for males, dashed lines are females, thick lines represent the landings component, and the thin lines represent the discarded component. The top left panel gives observed and predicted numbers-at-length in the discards and landings, top right gives the fishing mortality-at-length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed–expected) at length. The bottom right gives the Yield-per-recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.

12 FU17 inputs and methodology for catch options

An estimate of mean weight in the landings and discards is required to calculate catch options using the methodology developed by WKNEPH (ICES, 2009). The standard procedure recommends the use of a three year average but stock by stock decisions are needed if there are fluctuations. Sampling levels since 2008 have generally been good for FU17 but mean weights have been fluctuating. The IBPNeph concluded that the mean weights from 2008 should be used in the calculation of catch options. There have been changes on board retention ogives in the recent past mainly due to vessels with different behaviour joining the fishery. The IBP concluded that the last three years should be used for estimating the Discard proportion in number and the dead discard rate. Both the mean weights and discard rates will need to be kept under close review by WGCSE because of the Landings Obligation.

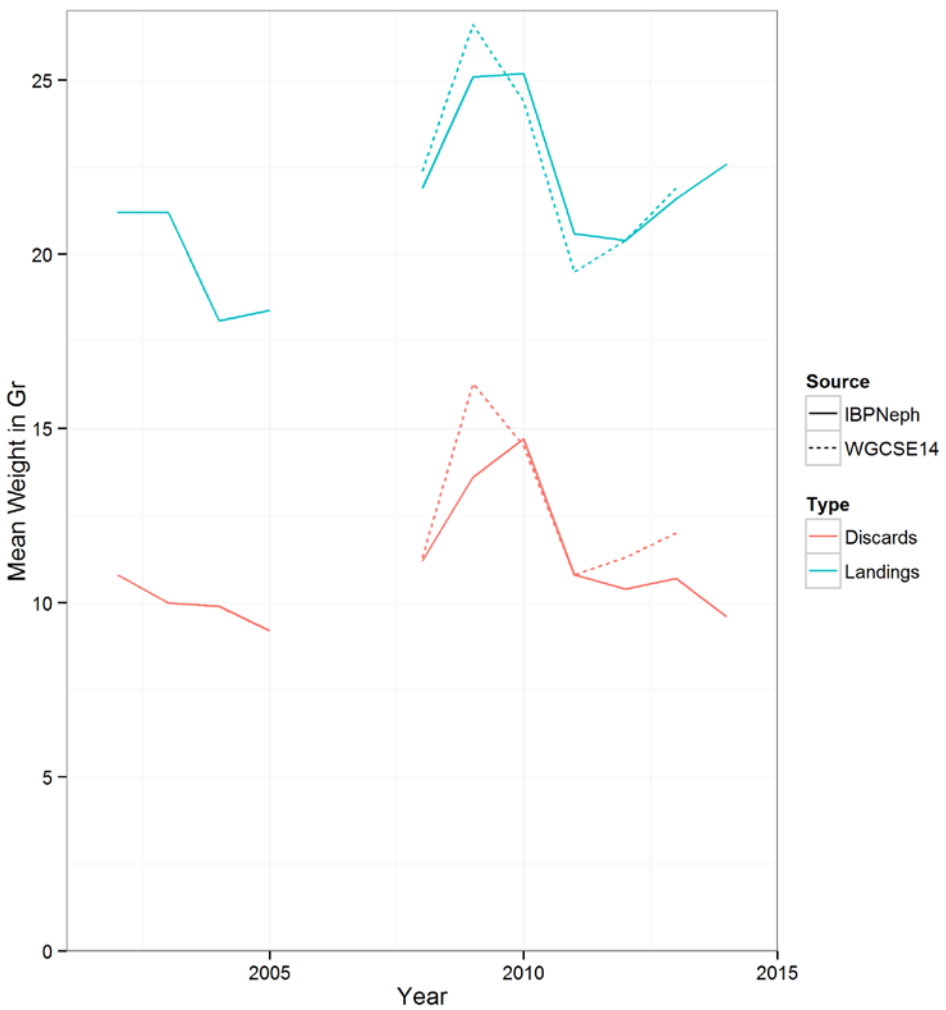

Figure 12.1. Time-series of mean weights in the landings and discards for FU17. The solid lines represents the recalculations by the IBPNeph with the new data raising procedures.

13 References

Doyle, J., Lordan, C., Fitzgerald, R., O'Connor, S., Fee, D., Butler, R., Stokes, D., Ni Chonchuir, G., Sheridan, M. and Simpson, S. 2015. Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2015 UWTV Survey Report and catch options for 2016. Marine Institute UWTV Survey report.

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ICES. 2006. Report of the Workshop on *Nephrops* Stocks. Annex 6: Working Document by Lordan and Gerritsen. ICES CM 2006/ACFM:12.

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Lee, J., South, A. B., and Jennings, S. 2010. Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. ICES Journal of Marine Science, 67: 1260–1271.

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McQuaid, N., R.P. Briggs, D. Roberts. 2006. Estimation of the size of onset of sexual maturity in *Nephrops norvegicus* (L.). Fisheries Research, 81(1), 26–36.

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. Mar Ecol Prog Ser 534:95–106.

14 Reviewers comments

There were three main areas requiring investigation as part of the inter-benchmark process for FU14 *Nephrops*:

- Revisions to the area of the *Nephrops* grounds based on recent multibeam, VMS and UWTV data.
- A review of current stock parameters (i.e. L/W, growth, maturity, M, discard survival), fishery data and raising procedures.
- Re-examine and update (if necessary) F_{MSY} proxies and MSY $B_{trigger}$.

FU14 Areas

The document described three methods for defining the area of fishable *Nephrops* distribution which result in slightly different total area estimates, all of which are a little lower than the previously estimated value. The co-krigged estimate which is the largest of the three (and around 10% higher than the VMS estimate) is put forward as the final value. The analysis to derive this estimate appears reasonable, but I would like to see a stronger justification for choosing the co-krigging approach over the VMS approach (as approaches using VMS data have been used to define the area of other *Nephrops* FUs e.g. North Minch and Devil's Hole). The document suggests that the current VMS estimate is likely to be an underestimate due to a lack of information on the <12 m vessels, are these additional areas places where the >12 m vessels (i.e. those with VMS) cannot fish for some reason? If there are no limits on where the >12 m vessels are able to fish, then it is not clear why these vessels would not be fishing across the whole area of fishable *Nephrops* distribution.

The VMS approach that is presented is somewhat different from other approaches which have made use of VMS data to estimate fished area e.g. the alpha convex hull approach described in WKNEPH 2013 and the grid method in Gerritsen *et al*. (?). It is not clear from the analysis presented how sensitive the approach is to some of the assumptions/choices e.g. 0.25 degrees cell size and using a 3% of total landings (seems a bit arbitrary) for the cut off for including grid cells. Potentially these assumptions could have an effect on the estimate of *Nephrops* distribution area.

Other comments/questions:

Why do the weight overlay and co-krigging methods use different year ranges for the survey data?

Why was 6 knots used as the maximum speed for VMS data? More usually 4.5 knots is used.

Is it sensible to assume that the landings per trip are distributed uniformly over all VMS pings from a trip? (Maybe better to assume uniform over the course of a day). Presumably vessels move if they have low catch rates?

What is Stephens (2015)? Reference missing.

Why does the weighted overlay method miss the top part of the ground? Is it do with the sediment data? The VMS and survey data indicate *Nephrops* in the area. (Might suggest the sediment data aren't much good then).

14.1 FU14 Stock parameters, fishery data and raising procedures

One of the main uncertainties in the assessment and forecast for this FU has been the lack of commercial sampling data in recent years. There are three data (catch sampling, observer sampling and market sampling) covering differing time frames with varying levels of sampling. The market sampling data are considered biased due a lack of sampling of the tailed component of the landings which do not appear on the markets with the whole animals. I agree with the conclusions of the IBP that it is appropriate that these data ought not to be considered further. The catch sampling and observer sampling data have been combined to provide catch length–frequency data. There is no comparison of length frequencies or mean sizes in the catch samples and observer data; the catch sampling relies on fishers to provide an unsorted (unbiased) sample of their catch. Has there been any analysis done to investigate whether these data are actually unbiased? (Fishermen may keep the big ones for themselves or alternatively fill the sample with big ones, if they think it will help the assessment). It would be nice to see. Furthermore, are the vessels which provide samples representative of the fishery as a whole? Presumably.

The derivation of the discard ogive seems reasonable and follows the same procedure as other *Nephrops* FUs and similarly the arguments for changing the discard survival rate are sensible.

The issues listed above also mention length–weight parameters, growth, maturity; presumably these were not updated due to a lack of new data?

14.2 FU14 Reference points

An update of the separable length cohort analysis and per-recruit analysis was run based on the 2013–2014 data. The fit of the LCA looks adequate and the results, in terms of selection pattern, look reasonable. It is interesting to note that the results show fairly even exploitation rates for males and females (and there is no reduction in F for larger females) which is unusual for *Nephrops* stocks (was that expected due to the timing of the fishery?)

The F_{MSY} proxy that has been chosen is a combined $F_{0.1}$; given that the burrow density is moderate and a combined $F_{35\%}$ results in SSB/R >20% virgin level then I would have thought that $F_{35\%}$ might be a more appropriate F_{MSY} proxy. (Similar to N Minch, S Minch). If you are choosing $F_{0.1}$ then I think you need further justification e.g. poorly understood, new/sporadic fishery, etc.

Overall, the IBP appears to have done a thorough job. It would be good to have further justification in the report on some of the choices which have been made (method for area estimation, choice of F_{MSY}). However, I consider that the work that has been done will result in a much improved basis for advice particularly the newly derived length–frequency data.

14.3 FU17

No specific comments on the revised FU17 area, stock parameters, fishery data, raising procedures or reference points were made by the FU17 reviewer.

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Annex 2: Stock Annex table

The table below provides an overview of the stock annexes updated by IBPNeph 2015. Stock annexes for other stocks are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular stock annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species,* and *acronym* of the relevant ICES expert group.

Stock ID	Stock name	Last updated	Link
nep-14	Irish Sea East *Nephrops* (FU14)	September 2015	*Nephrops* FU14
nep-17	Aran Grounds *Nephrops* (FU17)	October 2015	*Nephrops* FU17