Porcupine Bank *Nephrops* Grounds (FU16)
2014 UWTV Survey Report and catch options for 2015

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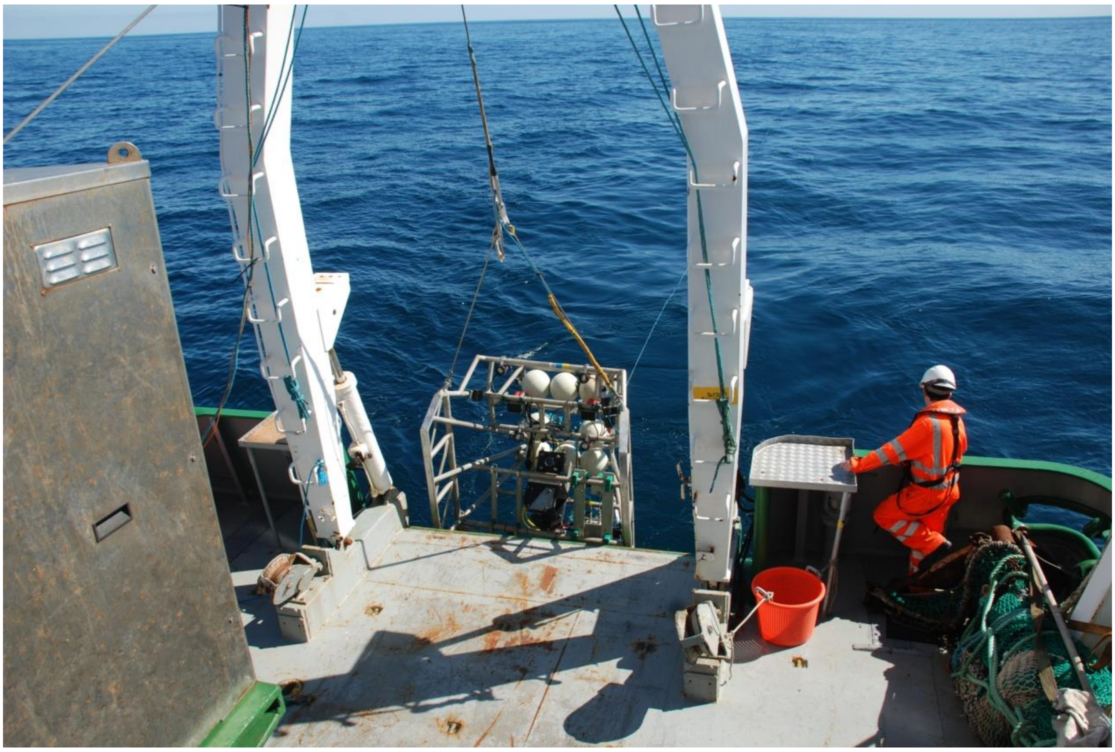

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Abstract

This report provides the results of the third underwater television on the ‘Porcupine Bank *Nephrops* grounds’ ICES assessment area; Functional Unit 16. The survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. In total 67 UWTV stations were successfully completed in a randomised 6 nautical mile isometric grid covering the full spatial extent of the stock. The mean burrow density observed in 2014, adjusted for edge effect, was 0.10 burrows/m². The final krigged abundance estimate was 722 million burrows with a relative standard error of 3% and an estimated stock area of 7,108km^2. The abundance estimate was 6% lower than in 2013. Landings options at various different fishing mortalities were calculated in line with the recommendations of WKNEPH 2013. Fishing at F_{msy} in 2015 implies catches of 1,850 t which close to the 2014 catch limit. This is because of an increase in average mean weight of the landings. The three species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangularis* and *Pennatula phosphorea*, were all observed during the survey. Trawl marks were also observed on over half of the stations surveyed.

Key words: *Nephrops norvegicus*, Porcupine Bank, stock assessment, geostatistics, underwater television (UWTV), benthos.

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Introduction

The prawn (*Nephrops norvegicus*) are common around the Irish coast occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in VII is extremely valuable with 2013 landings worth in excess of € 80 m at first sale. The *Nephrops* fishery on the Porcupine Bank takes place on a large area approximately 7,100 km² of complex muddy habitat between depths of between 330-570m. The fishery typically yields very large individual *Nephrops* that attain very high market prices relative to other fisheries around Ireland. International landings from the fishery peaked in the early 1980s around 4,000 tonnes but have shown a declining trend since then with some fluctuations (ICES, 2014). The total estimated landings in 2013 were 1,140 t which were likely to be worth in the region of €9.5 m.

In the recent past sustainability of the Porcupine Bank *Nephrops* stock has been a major concern. Consequently a spatio-temporal closed area was developed and proposed by the NWWRAC and implemented between 1st June and 31st July in 2010-2012. Since 2013 the fishery was closed for one month from 01st to 31st of May. Since 2011 a functional unit catch limit (actually landings) has also in place as part of the TAC regulation (ICES, 2014). These measures were introduced due to negative trends in the various indicators used to assess the stock and ICES advice for a closure of the fishery in 2009 and 2010. The stock situation is known to have improved since 2010 following a good recruitment. Scientific information for this area has also improved with the introduction of a dedicated Irish fisheries-science partnership trawl survey between 2010 and 2012 and the provision of commercial grade data by the Irish fishing industry since 2010 (ICES, 2014).

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced many factors; time of year, light intensity and tidal strength. Underwater television surveys and assessment methodologies have been developed by ICES to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009 & 2013). The first UWTV survey of the Porcupine Bank *Nephrops* grounds (FU16) was carried out in 2012 (Lordan, et al. 2012). That survey was used to provide catch advice for 2013. Subsequently, ICES carried out a benchmark assessment of the Porcupine Bank *Nephrops* stock which concluded that the UWTV survey was a suitable basis to assess and provide management advice (ICES, 2013a).

This was the third UWTV survey of the Porcupine Bank *Nephrops* grounds (FU16). The survey was multi disciplinary in nature and the specific objectives are listed below:

1. To obtain 2014 quality assured estimates of *Nephrops* burrow densities from a randomised isometric grid of UWTV stations at 6 nautical mile spacing over the known spatial and bathymetric distribution of the stock (Figure 1).
2. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
3. To collect oceanographic data using a sledge mounted CTD.

This report details the final results of the survey and provides catch options for 2015 in line with the recommendations and procedures outlined at the 2013 ICES benchmark (ICES, 2013a).

Material and methods

A randomised isometric gird of stations at 6 nautical mile or 11.1km intervals was planned for the area. The boundary use to delineate the edge of the ground was based on VMS data of fishing activity between 2006-2011 targeting *Nephrops* (shown in Figure 1 and presented Table 1 of Lordan et al. 2012). The grid spacing was determined based on a time constraints of getting the survey completed within a time window of around 5-6 days. This resulted in 67 planned stations. Data on bathymetry and backscatter were also available from the Irish National Seabed Survey and INFOMAR project (http://www.infomar.ie/). The stations ranged from 340-560 m in depth with an average depth of around 440 m (Figure 1).

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded onto DVD. Time referenced video footage was collected from a video camera with field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). The USBL navigational data was used to calculate distance over ground or 'DOG' for all of stations.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and footage from the 2013 Porcupine Bank survey, prior to recounting at sea (ICES, 2009b). Once this process had been undertaken, all recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey. During this review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a standard classification key. The numbers of *Nephrops* burrows complexes (multiple burrows in close proximity which appear to be part of a single complex are only counted once) were individually time stamped during the verification process and any discrepancies were checked. *Nephrops* activity in and out of burrows were also counted. SGNEPS recommended that verification recounts should be 7 minutes (ICES, 2009b) but this was increased to 10 minutes for the Porcupine. This was because at the lower densities observed the relative scale of variation between minutes was higher than typical in other areas. Recounting more minutes resulted in a more stable mean density estimates for each station.

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011). Finally, if there was any time during each minute where counting was not possible, due to sediment clouds or other reasons, this was recorded and removed from the distance over ground calculations. The "r" quality control tool allowed for individual station data to be analysed in terms of data quality for navigation, overall tow factors such as speed and visual clarity and consistency in counts (an example is given in Figure 2). Consistency and bias between individual counters was examined using Figure 3. Because each burrow was time stamped and agreed the discrepancies in Figure 3 were for minutes not used in the analysis.

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. All recounts were carried out on the footage with a FOV of 75cm. This assumes that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed for all tows using lasers. The burrow systems in this area are relatively large and occurred at low density making the verification recounts relatively easy. Figure 4 shows the variability in density between minutes and operators (counters) for each station. These show that the variability between minutes was high reflecting the patchy low density and consistency between counters was very high reflecting the fact that burrow identification was relatively easy.

To account for the spatial co-variance and other spatial structuring a geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. The mid-points of each UWTV transect were converted to meters using UTM zone 28. As last year an unweighted and unsmoothed omnidirectional variogram was constructed with a lag width of approximately 3.0 km and maximum lag distance of between 73 km. The same logarithmic variogram model was fitted using the SURFER algorithm and used to create kriged grid file of interpolated burrow density. The final part of the process was to limit the calculations to the known extent of the ground using the boundary blanking file. The resulting blanked grid was used to estimate the domain area and total burrow abundance estimate. Kriged estimation variance or CV was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997). The EVA burrow abundance estimates were extremely close to the Surfer estimate.

A CTD profile was logged for the duration of each tow using a Sea-Bird SBE37. This data was linked to the ships position using a synchronised time stamp. Average bottom temperature and salinity were plotted using SURFER.

Results

A summary of the univariate statistics and geostatistics on the burrow density estimates are given in Table 1. The mean burrow density observed in 2014, adjusted[1] for edge effect, was 0.10 burrows/m². The range of the observations was relatively high from 0.00-0.23 burrows/m². Most of the salient summary statistics (mean, median, trimmed mean, percentiles etc.) on the observations in 2014 were around 7% lower than in 2013. Histograms of the observed burrow densities observation from 2012 to 2014 for the Porcupine Bank are shown in Figure 5.

The final modelled density surfaces from 2012 to 2014 are shown as a heat maps and bubble plots in Figure 6. The scale and spatial pattern of burrow density is relatively consistent in both years. In 2012 a conservative assumption was made about densities declining towards zero towards the south of the area. The 2013 survey with better spatial coverage show that the densities in the middle of the south of the ground and

[1] Note the "adjusted" density estimates in this report are adjusted by dividing by 1.26 to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

south west do not decline towards zero. The 2014 burrow surface was fairly homogeneous with an area of higher density in the middle of the ground. The abundance estimate derived from the krigged burrow surfaces (and adjusted for edge effect) declined by 6% from 768 million burrows in 2013 to 722 million in 2014 (Table 1). The estimated area of the ground or domain area was 7,108km². The estimation CV on the abundance was around 2.5% in 2014.

Fishing mortality reference points and mean weight of *Nephrops* in the landings from the Porcupine Bank after WGCSE 2013 are given in Table 2 and Table 3 respectively (ICES, 2013a). Landings options at various different fishing mortalities are calculated in line with the recommendations of WKNEPH 2013 and are shown in Table 4. Fishing at F_{msy} in 2015 implies catches of 1,850 t which is very close to the 2014 catch limit (1,848 t).

Trawl marks were observed at 54% of surveyed stations and 12% of surveyed stations had trawl marks persisting throughout the 10 minute transect. The distribution and abundance class of the various sea-pen species observed on the UWTV footage is shown in Figure 7. Three sea-pen species occur in the deep mud habitats around the coastal British Isles; *Virgularia mirabilis, Pennatula phosphorea* and *Funiculina quadrangularis* (Hughes, 1998). All three species were observed on footage during the 2014 survey.

The CTD data collected are summarised in Figure 8. The temperature at the sea bed varied by only around half a degree from 9-10.5^{o}C over the area surveyed. The warmest water on the sea bed was in the northern and eastern part of the ground. Highest salinities were observed at the deepest stations along the east and south facing slope of the bank. Lowest salinities were in the middle of the ground. Interestingly temperature and salinity at station 7 was slightly different to surrounding observations.

Discussion

This was the third systematic UWTV *Nephrops* survey of the Porcupine Bank. The distance from shore (~ 120 nautical miles), exposed nature of the area, the significant water depths involved (330-570m) and relatively large size of the area (>7100km^2) presents significant logistical, technical and survey design challenges. The Marine Institutes carries out UWTV surveys in three 10 day pre-planned survey legs. Priority was given to the Porcupine Bank which was successfully completed on the first leg in 2014. The visibility and footage quality was normally excellent, burrow morphology and size were similar to other areas and the relatively low density meant that burrow identification was relatively easy. In 2014 all burrows included in the analysis were individual time stamped in the UWTV footage.

The survey design, with a randomised 6 nautical mile isometric grid and fixed ground boundary, was the same as that used previously (Lordan, et al. 2012). The total abundance estimate has declined slightly. Catch options for 2015 have been calculated using updated mean weight data from WGCSE 2014 and in line with the stock annex (ICES, 2014). The resulting catch advice for 2015 fishing at F_{msy} is very similar to last year mainly due to an increase in estimated mean weight of the landings. Carrying out annual UWTV surveys to generate catch advice, while challenging, should be continued in the short term given the limited number of UWTV observations to date and evolving knowledge base on the spatial and temporal dynamics of this stock.

In addition to estimating *Nephrops* stock abundance UWTV surveys can be used to monitor the presence of certain benthic fauna (ICES, 2011). Sea-pens and burrowing megafauna communities have been included in the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2010). As previously observed all three species sea-pen species which occur on mud habitat around Ireland are found on the Porcupine Bank. The occurrence of *F. quadrangularis* in particular is significant since that species is particularly vulnerable to trawl mortality. *Funiculina quadrangularis* is largely absent from other *Nephrops* grounds around Ireland although there are catches on groundfish surveys in areas where *Nephrops* are not commercially fished (Power and Lordan, 2012). The majority of the Porcupine Bank is fished at least once annually based on the methods described in Gerritsen, et al (2013). The observation that over 50% of stations showed some trawl marks is relatively high but consistent with previous years. The CTD data collected during UWTV surveys will over time prove to be a data asset in monitoring changes to the environment on *Nephrops* grounds.

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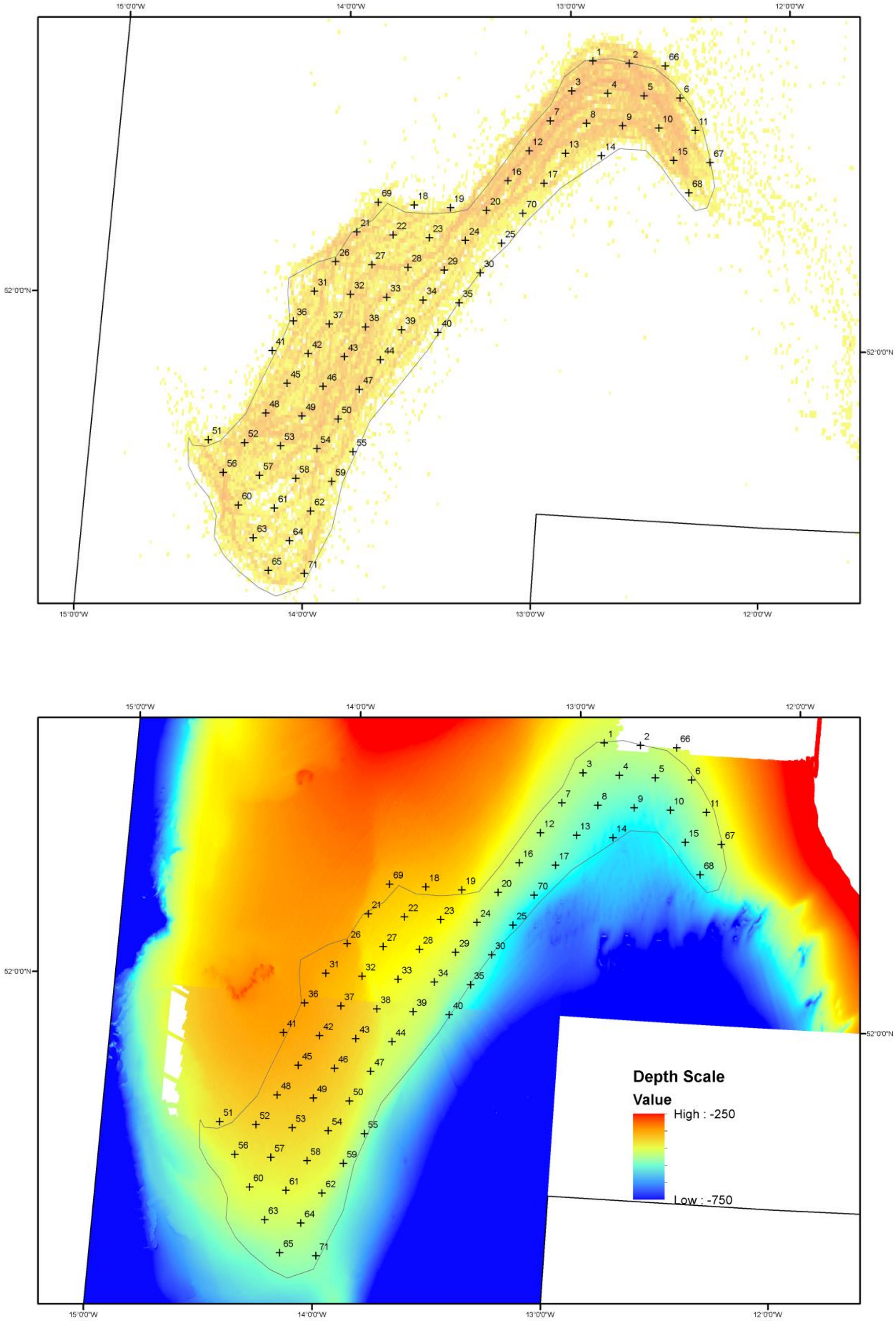

Figure 1: Porcupine Bank 2014 UWTV map of station positions overlaid on a heat map of *Nephrops* directed fishing (top panel) and bathymetry (bottom panel). The black polygon line indicated the ground boundary currently used.

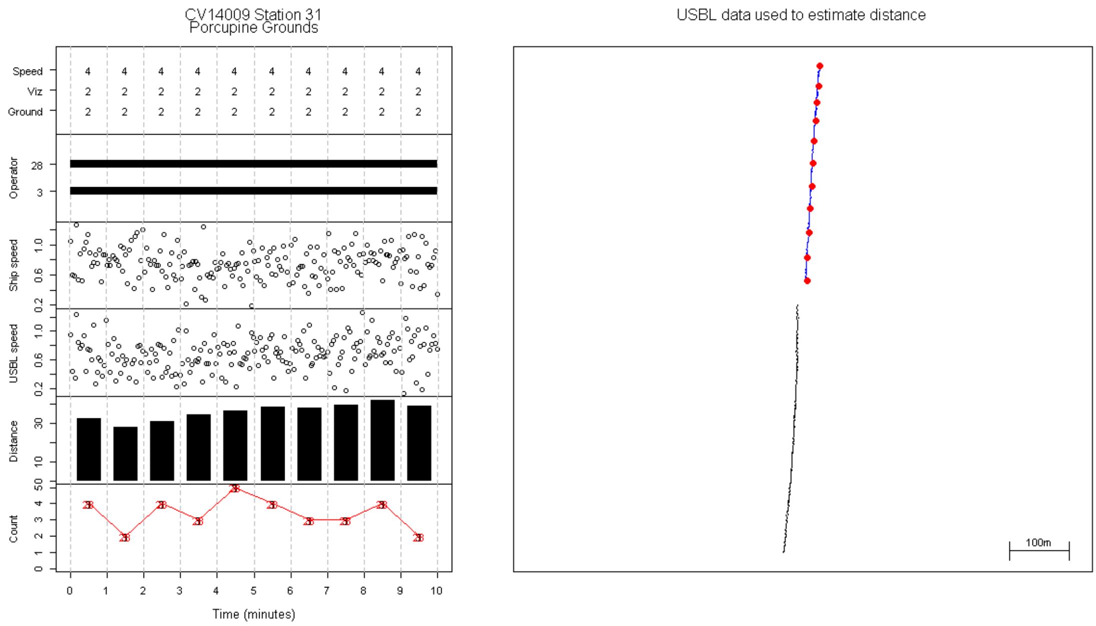

Figure 2. Porcupine Bank 2014 UWTV example quality control plot for the navigational and recount data.

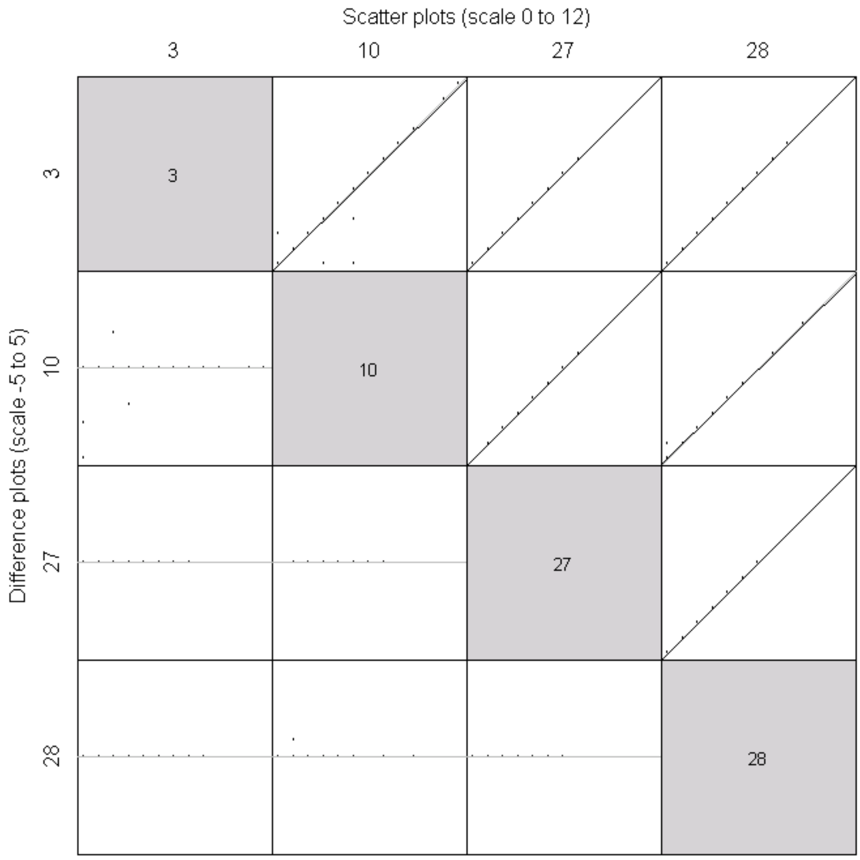

Figure 3. Porcupine Bank 2014 UWTV inter counter comparison plot.

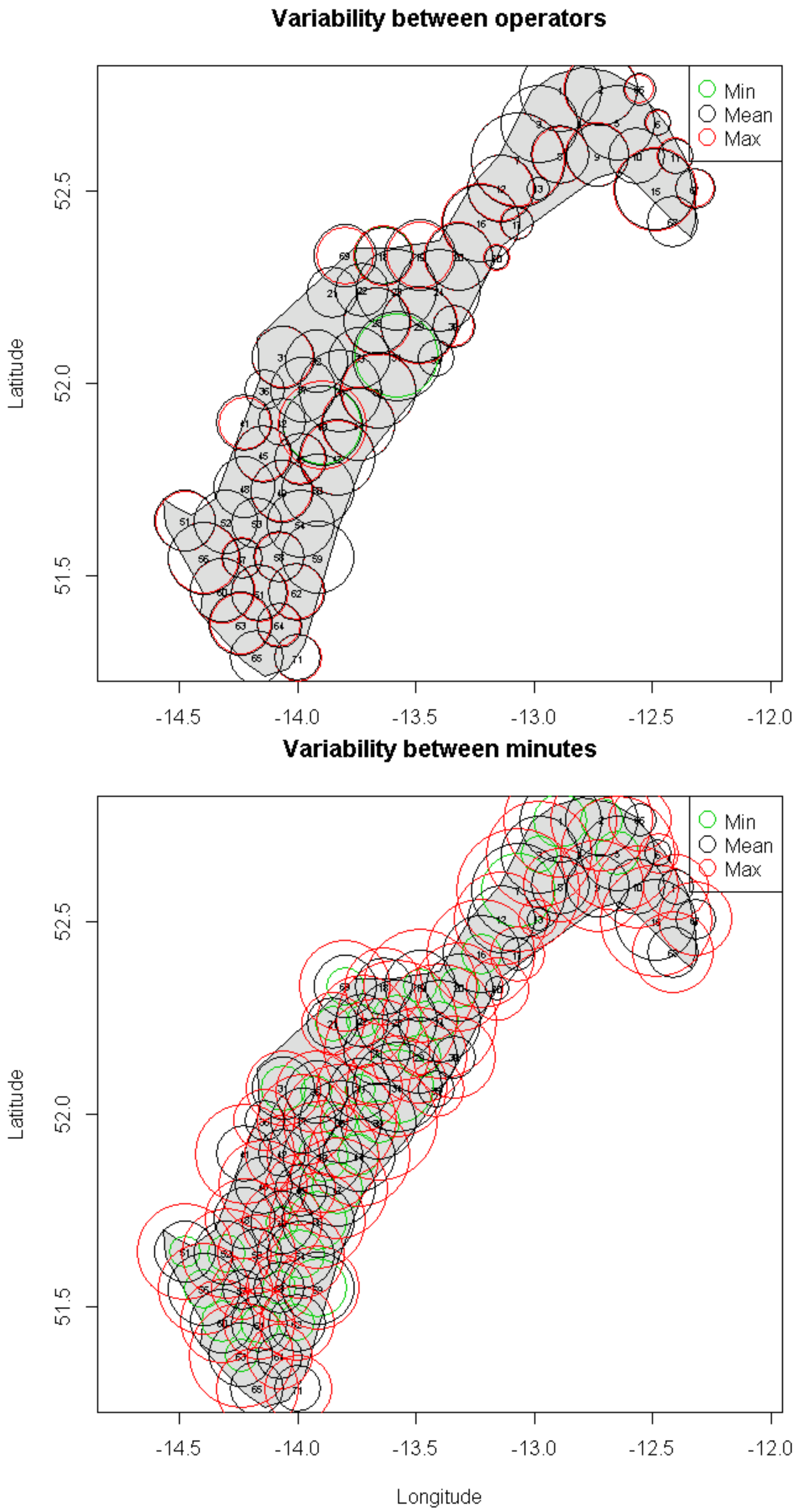

Figure 4: Porcupine Bank 2014 UWTV quality control plot showing variability between counters (top panel) and between minutes (bottom panel) for each UWTV station

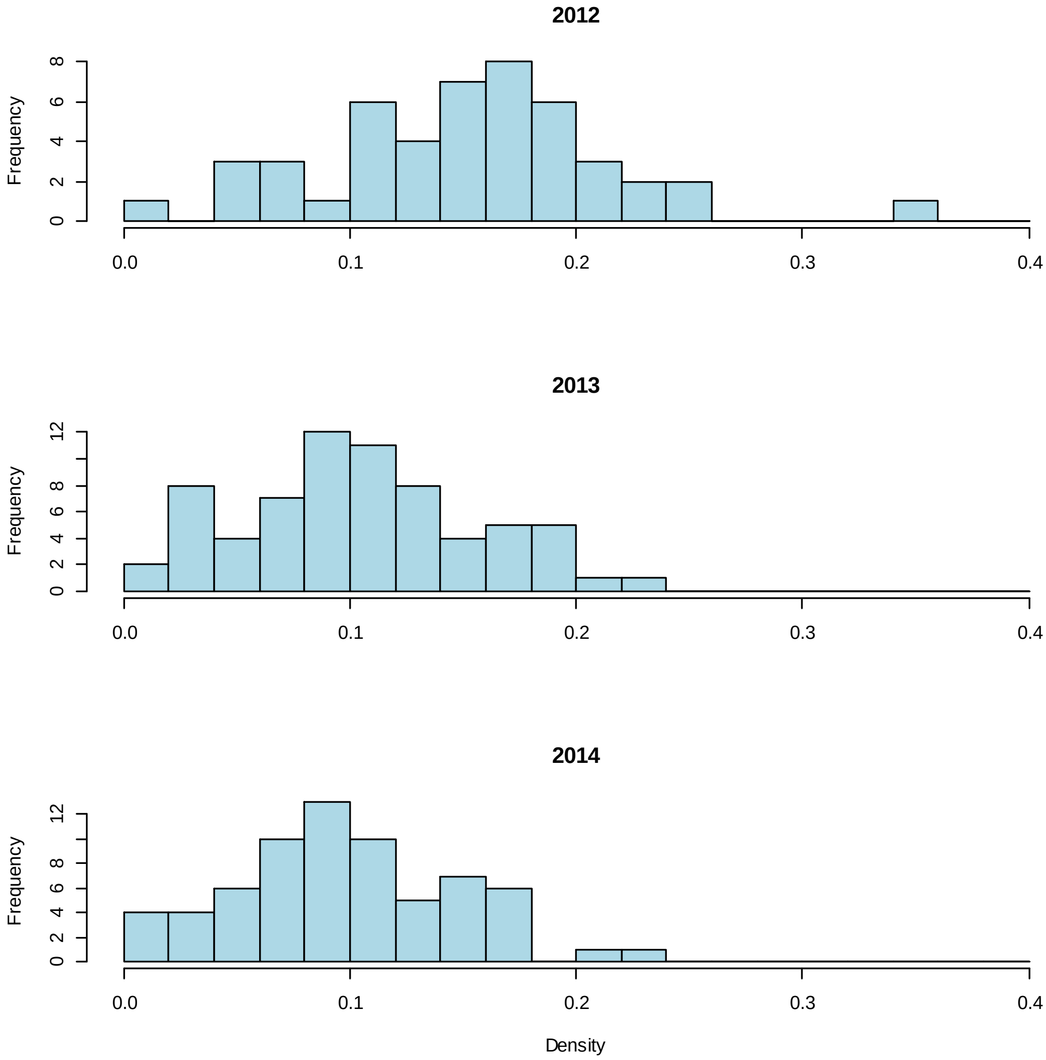

Figure 5: Porcupine Bank 2014 UWTV histogram of observed burrow densities between 2012 and 2014.

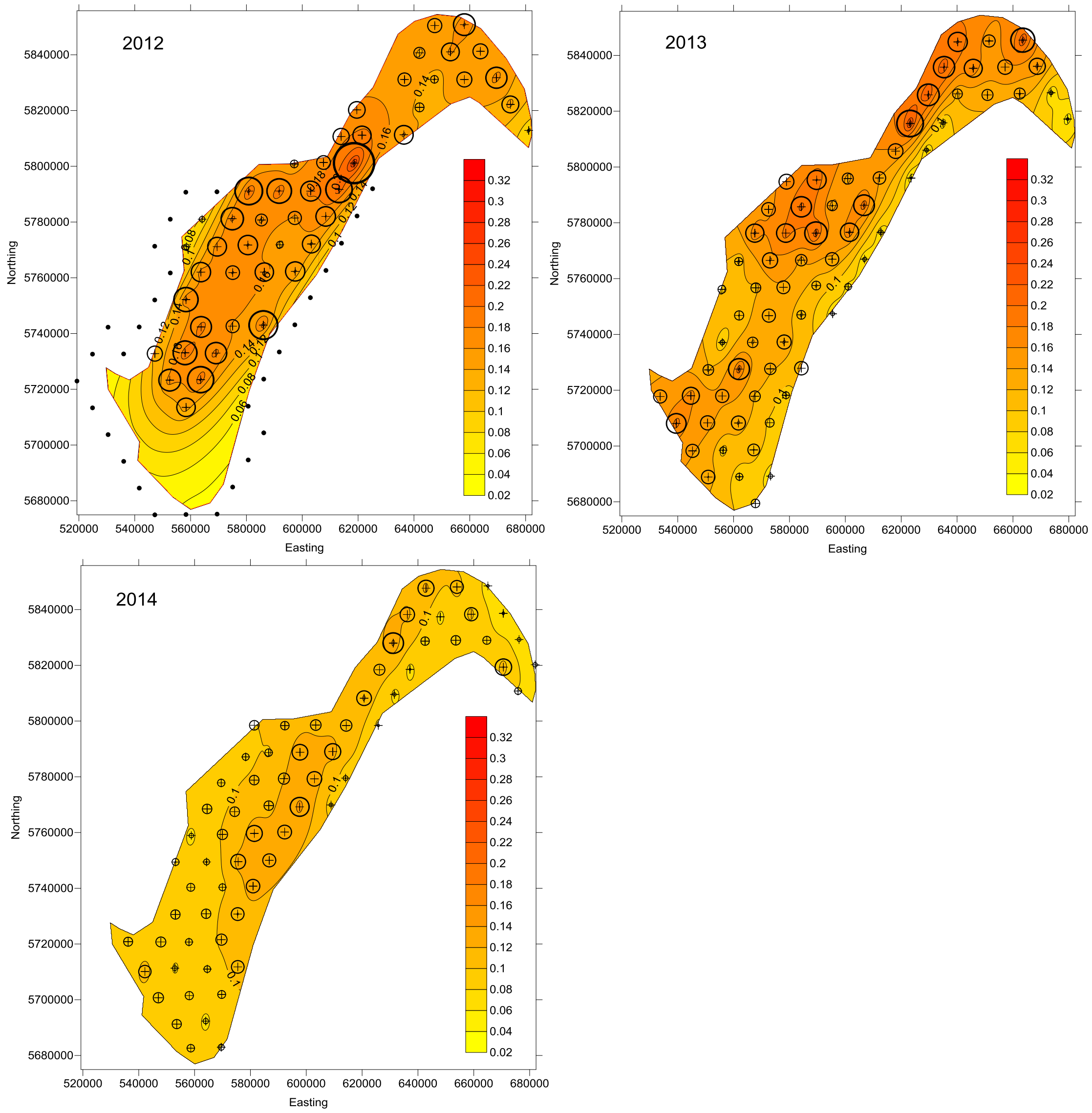

Figure 6: Porcupine Bank UWTV bubble plot of the burrow density observations overlaid on a head map of the krigged burrow density surface for 2012-2014. Observed station positions are indicated using a + and assumed zero densities beyond the boundary are shown as black filled circle.

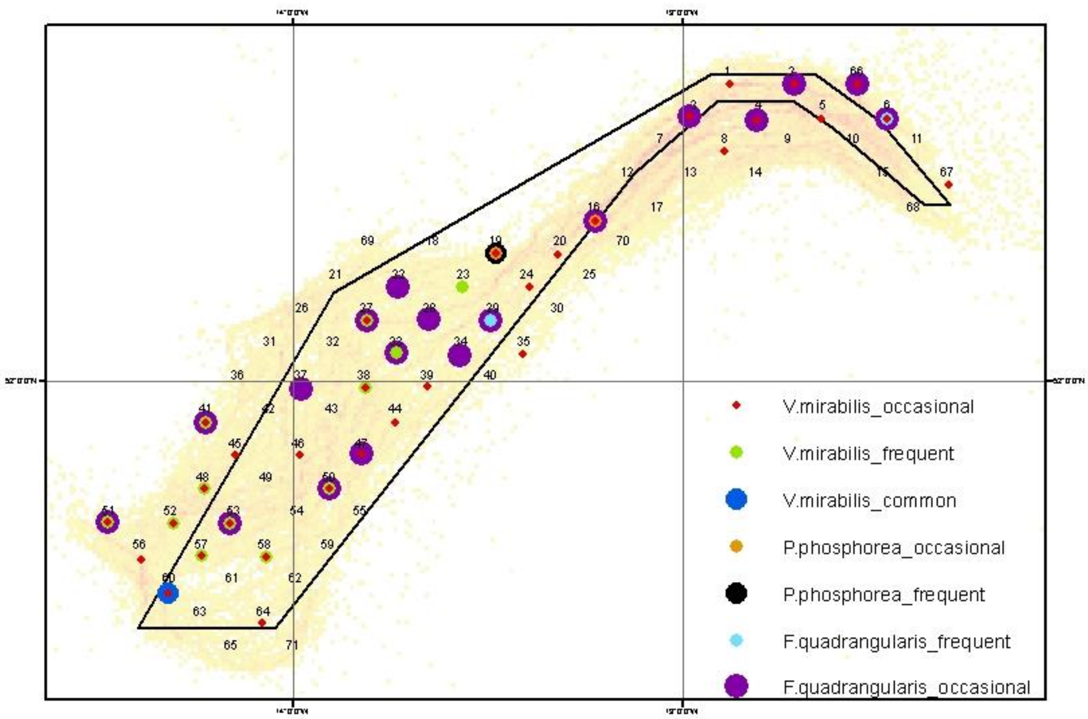

Figure 7: Porcupine Bank UWTV 2014. The distribution and abundance class of sea-pen species observed on the video footage.

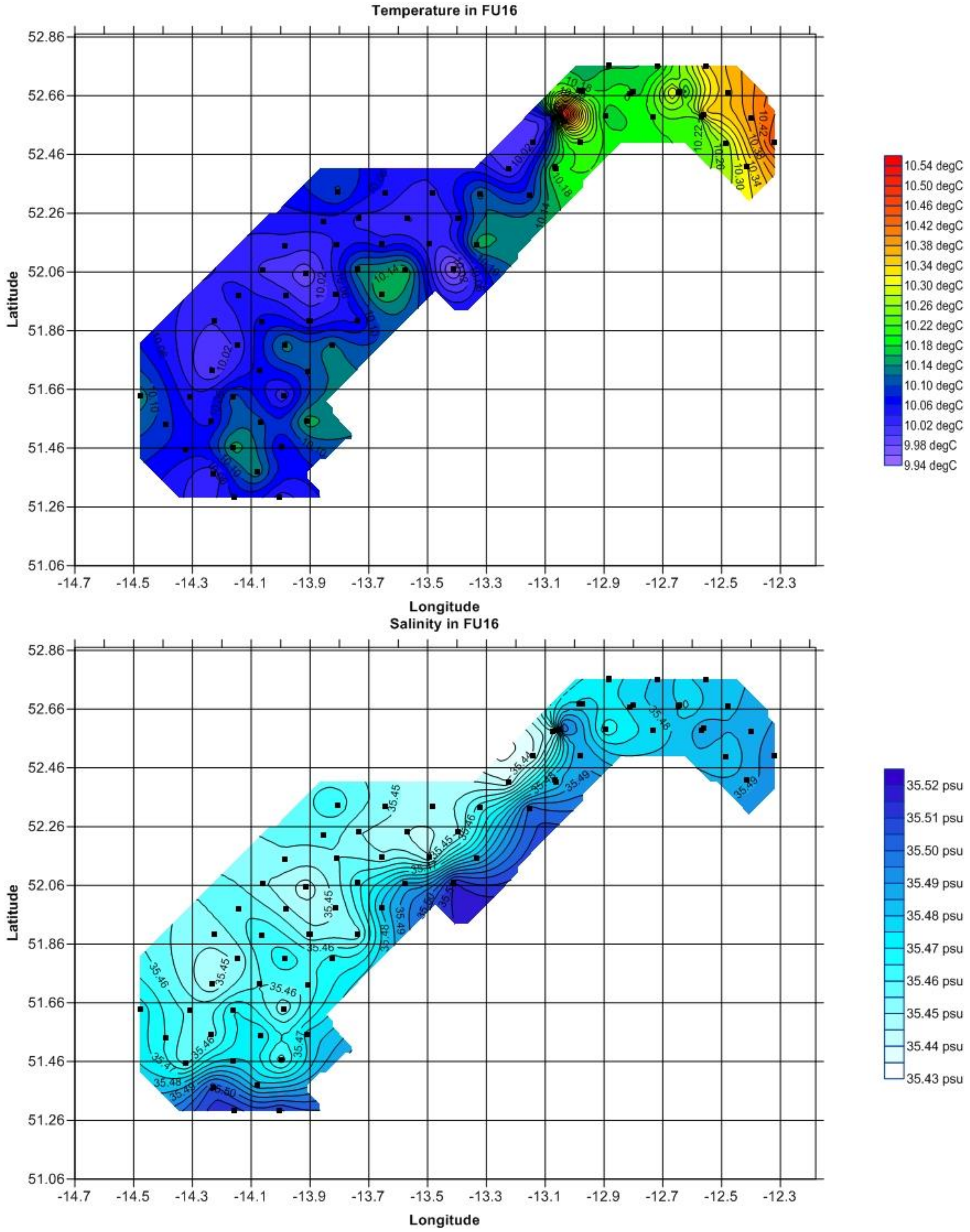

Figure 8: Porcupine Bank UWTV 2014. Temperature and salinity data on the seabed collected during the survey.

Table 1: Summary of univariate statistics and geostatistics for the burrow density estimates (bias corrected) on the Porcupine Bank UWTV survey in 2012-2014.

Univariate Statistics	**2012**	**2013**	**2014**
Number of Observations	47	68	67
Minimum:	0.014	0.012	0
25%-tile:	0.113	0.072	0.068
Median:	0.158	0.106	0.099
75%-tile:	0.187	0.140	0.136
Maximum:	0.358	0.233	0.226
Midrange:	0.187	0.122	0.113
Range:	0.344	0.221	0.226
Interquartile Range:	0.074	0.067	0.049
Median Abs. Deviation:	0.037	0.034	0.034
Mean:	0.151	0.106	0.099
Trim Mean (10%):	0.149	0.104	0.097
Standard Deviation:	0.063	0.051	0.049
Variance:	0.005	0.003	0.002
Coef. of Variation:	0.329	0.385	0.498
Coef. of Skewness:	0.294	0.198	0.238
Geostatistics	**2012**	**2013**	**2014**
Adjusted abundance estimate (millions)	787	768	722
Domain area (km^2)	7108	7108	7108
Coef. of Variation	0.049	0.044	0.025

Table 2. Porcupine Bank *Nephrops* estimated Per Recruit Reference Points and associated harvest ratios (ICES, 2013b).

			Fbar(35-50 mm)		HR	SPR (%)		
		Fmult	M	F	(%)	M	F	T
$F_{0.1}$	M	0.15	0.140	0.034	4.2	39.9	79.3	53.9
	F	0.76	0.709	0.172	12.3	9.7	41.5	21.0
	T	0.19	0.177	0.043	5.0	33.6	75.0	48.4
F_{max}	M	0.28	0.261	0.063	6.6	24.4	66.8	39.5
	F	1.81	1.688	0.410	19.0	4.6	22.6	11.0
	T	0.63	0.588	0.143	11.1	11.5	46.3	23.9
$F_{35\%SpR}$	M	0.19	0.177	0.043	5.0	33.6	75.0	48.4
	F	1	0.933	0.226	14.3	7.6	34.8	17.2
	T	0.35	0.326	0.079	7.7	20.0	61.5	34.8

Table 3. Porcupine Bank *Nephrops*: Summary of UWTV abundance, harvest ratio, landings numbers and mean weight in the landings.

Year	UWTV abundance (millions)	95% CI	Harvest ratio	Landings by number (millions)	Mean weight in landings (g)
2011	na	na	na	na	45.8
2012	787	78.7	3.2%	25.0	50.4
2013	768	61.4	2.6%	19.8	57.5
2014	722	35.4	na	Na	Na

Table 4: Porcupine Bank *Nephrops* catch options for 2015.

Outlook for 2015

Basis: $F_{2014} = F_{2012\text{-}2013}$ = 2.6%, Absolute survey abundance index (2015) = 772 million (2014 index); Mean individual weight in landings (2011–2013) = 51.2 g, Discard rate (dead, by number = 0%**).

Basis	Total Catches*	Landings	Dead Discards**	Surviving Discards**	Harvest Rate
	L+DD+SD	L	DD	SD	for L+DD
MSY approach	1850	1850	0	0	5.0%
$F_{2012\text{-}13}$	1073	1073	0	0	2.9%
$F_{35\%SpR}$	2848	2848	0	0	7.7%
F_{max}	4,106	3884	0	0	11.1%

Weights in tonnes.
* Total catches are the landings plus dead and surviving discards.
** Based on negligible discards during observer trips.