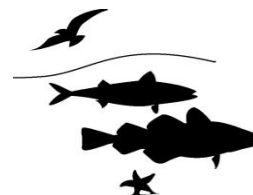




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Foras na Mara



Porcupine Bank *Nephrops* Grounds (FU16) 2017 UWTV Survey Report and catch options for 2018

Colm Lordan¹, Jennifer Doyle¹, Rosemarie Butler¹, Sharon Sugrue¹, Chris Allsop¹, Seán O'Connor¹, and Jean-Philippe Vacherot².

¹ Marine Institute, Oranmore, Galway, Ireland.

² Ifremer, 8 Rue François Toullec, 56100 Lorient, France.



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Abstract

This report provides the results of the fifth 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 63 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 2017, adjusted for edge effect, was 0.12 burrows/m². The final krigged abundance estimate was 850 million burrows with a relative standard error of 5% and an estimated stock area of 7,134 km². The 2017 abundance estimate was 11% lower than in 2016. Using the 2017 estimate of abundance and updated stock data implies catch of 2,734 tonnes and landings of 2,734 tonnes in 2017 when MSY approach is applied (assuming that all catch is landed). The three species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangularis* and *Pennatula phosphorea*, were all observed during the survey. The deepwater sea-pen *Kophobelemnion stelliferum* was also observed and its presence/absence mapped from the available time-series. Trawl marks were also observed on 43% of the stations surveyed.

Key words: *Nephrops norvegicus*, Porcupine Bank, stock assessment, geostatistics, underwater television (UWTV), sea-pens, 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 ICES sub-area 7 is extremely valuable with 2016 landings worth in excess of € 107 million 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, 2017). The total estimated landings in 2016 were 2,154 t which were likely to be worth in the region of €16.7 million.

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. Assessment methodologies, based on underwater television surveys, have been developed by ICES to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009 & 2013). Since 2012, UWTV surveys have been used to assess and provide catch advice for this stock (ICES, 2013).

This was the fifth 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 2017 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 UWTV results of the 2017 survey and also documents other data collected during the survey. Operational survey details are available in form of a

survey narrative from the scientist in charge (CL). The 2017 abundance are used to generate catch options for 2018 in line with the recommendations and procedures outlined at the 2013 ICES benchmark (ICES, 2013) and in stock annex (ICES, 2016a) and using the F_{msy} reference points proposed by FMSYREF4 (ICES, 2016b).

Material and methods

A randomised isometric grid of stations at 6 nautical mile or 11.1km intervals was planned for the area. The boundary used 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 64 planned stations and were generated using the `spsampl` function in the `sp` package (Pebesma & Bivand, 2005) of `r` (R Core Team, 2017). 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 345-562 m in depth with an average depth of 448 m (Figure 1). Survey timing was generally standardised to June each year. In 2015 the national research vessel broke down prior to the survey and the survey was not carried out despite several attempts to get to this ground.

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). *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 and a key was devised to categorise the densities of sea-pens based SACFOR abundance scale (Table 1) after 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).

In 2017 the survey count data was screened to check for any unusual discrepancies using Lin’s Concordance Correlation Coefficient (CCC) with a threshold of 0.6. Lin’s CCC (Lin, 1989) measures the ability of counters to exactly reproduce each other’s counts on a scale of 1 to –1 where 1 is perfect concordance (i.e. a pairwise plot will have all points lying along the 1:1 line. A value of –1 would be generated by all points lying on the –1:1 line and a value of 0 indicates no correspondence at all. This analysis resulted in 9 stations that required a third counter approximately 14% of total TV stations. For those stations that did not pass the threshold it was deemed appropriate to inspect the CCC plots and then to use the 3 counters in the final counts. Lin’s CCC quality control plots of count data for stations 120 to 122 are shown in Figure 3. Consistency and bias between individual counters was examined using Figure 4.

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 5 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.

From 2012-2014 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 and the krigged estimation variance or CV was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997).

Since 2016 the geostatistical analysis was carried out using RGeostats package Version 11.1.1 (Renard D., *et al*, 2015) and is available as a separate R markdown document. The same basic steps were carried out as in previous years; construction of experimental variogram, a model variogram (h), was produced with an exponential model, create krigged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and calculate survey precision.

A CTD profile was logged for the duration of each tow using a Sea-Bird SBE37. The sensor takes readings every 5 seconds and will be processed at a later stage to calculate an average bottom temperature and salinity for each cast.

Results

In 2017 63 stations were completed successfully on the Porcupine Bank. Figure 5 shows bubble plots of the variability between minutes and operators. At the lower densities observed the relative scale of variation between minutes was higher than typical in other areas.

A combined violin and box plot of the observed burrow densities is presented in Figure 6. This shows that median and mean burrow densities are similar in most years. The inter-quartile range is also similar. The mean burrow density observed in 2017, adjusted¹ for edge effect, was 0.12 burrows/m². The range of the observations was relatively high from 0.01-0.5 burrows/m².

The final modelled density surfaces from 2012 to 2017 are shown as a heat maps and bubble plots in Figure 7. The 2017 burrow surface shows an area of higher density in the north of the ground. The abundance estimate derived from the krigged burrow surfaces (and adjusted for edge effect) decreased by 11% from 958 million burrows in 2016 to 850 million in 2017 (Figure 8 and Table 2). The estimated area of the ground or domain area was 7,134 km². The estimation CV on the abundance was around 5.3% in 2017.

Trawl marks were observed at 43% of surveyed stations and 3% 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 9. 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 2017 survey. The presence/absence of the sea-pen *Kophobelemnion stelliferum* is shown in Figure 10 as part of a species review in the UWTV database. It has not been observed to date on the north-eastern part of the ground which is the deepest. This species has been recorded at the Porcupine Seabight in depths to 1600 m (Rice et al., 1992).

The UWTV abundance data together with data from the fishery; landings, removals in number, and mean weight in the landings are shown (Table 3). The basis to the catch options table is given in Table 4. The harvest rate (calculated as (landings + dead discards)/(abundance estimate) is based on a linear extrapolation of abundance for 2015 as no TV survey was carried out. The catch and landings options at various different fishing mortalities are calculated in line with the stock annex using the 2017 survey abundance are presented in Table 5.

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).

Discussion

This was the fifth 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 (>7100km²) 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 2017. 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 2017 all burrows included in the analysis were individually 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 increased slightly. Catch options for 2018 have been calculated using updated mean weight data from WGCSE 2017 - average over the time series 1986 to 2016 to account for variability as in done for FU22 (ICES, 2016). The resulting catch advice for 2018 fishing at the new F_{msy} is a decrease mainly due to a decrease in TV abundance estimate. 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 30% of stations showed some trawl marks is 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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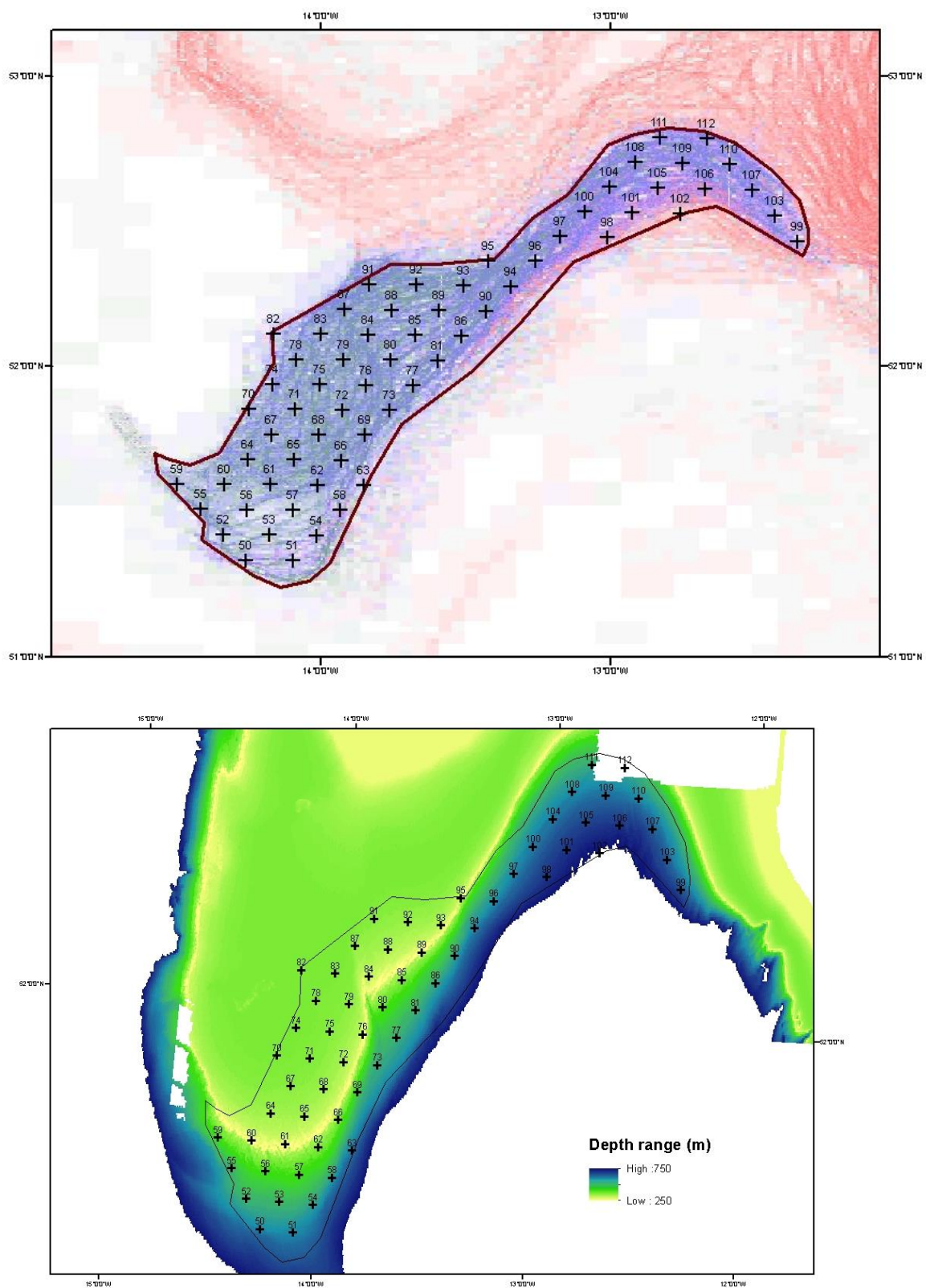


Figure 1. Porcupine Bank 2017. UWTV map of station positions overlaid on a heat map of *Nephrops* directed fishing (top panel) and (bottom panel). The black polygon line indicates the ground boundary currently used.

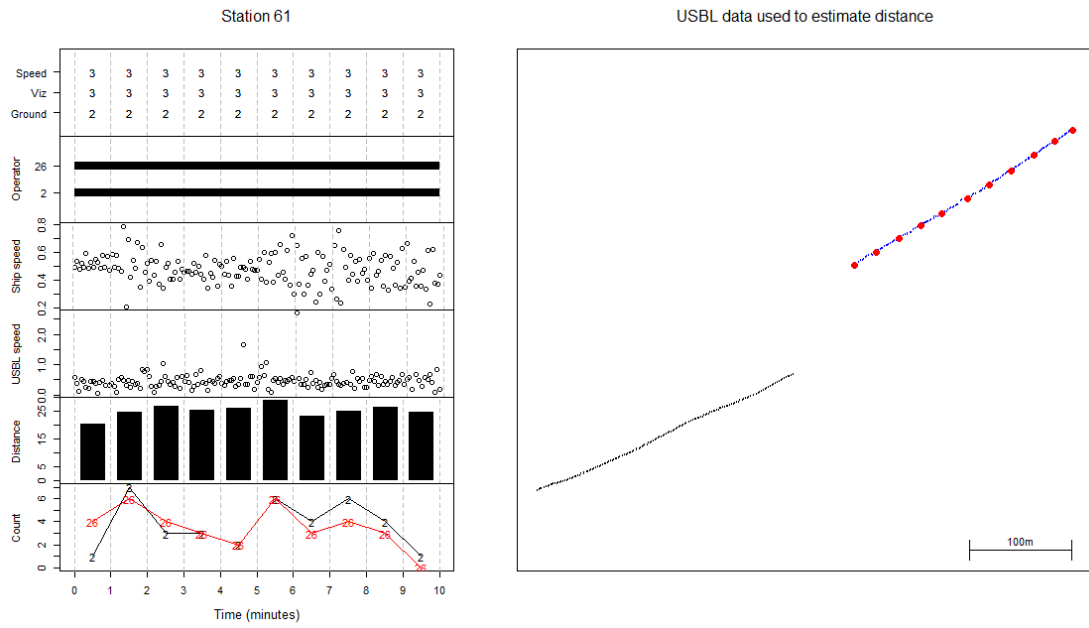


Figure 2. Porcupine Bank 2017. UWTV example quality control plot for the navigational and recount data.

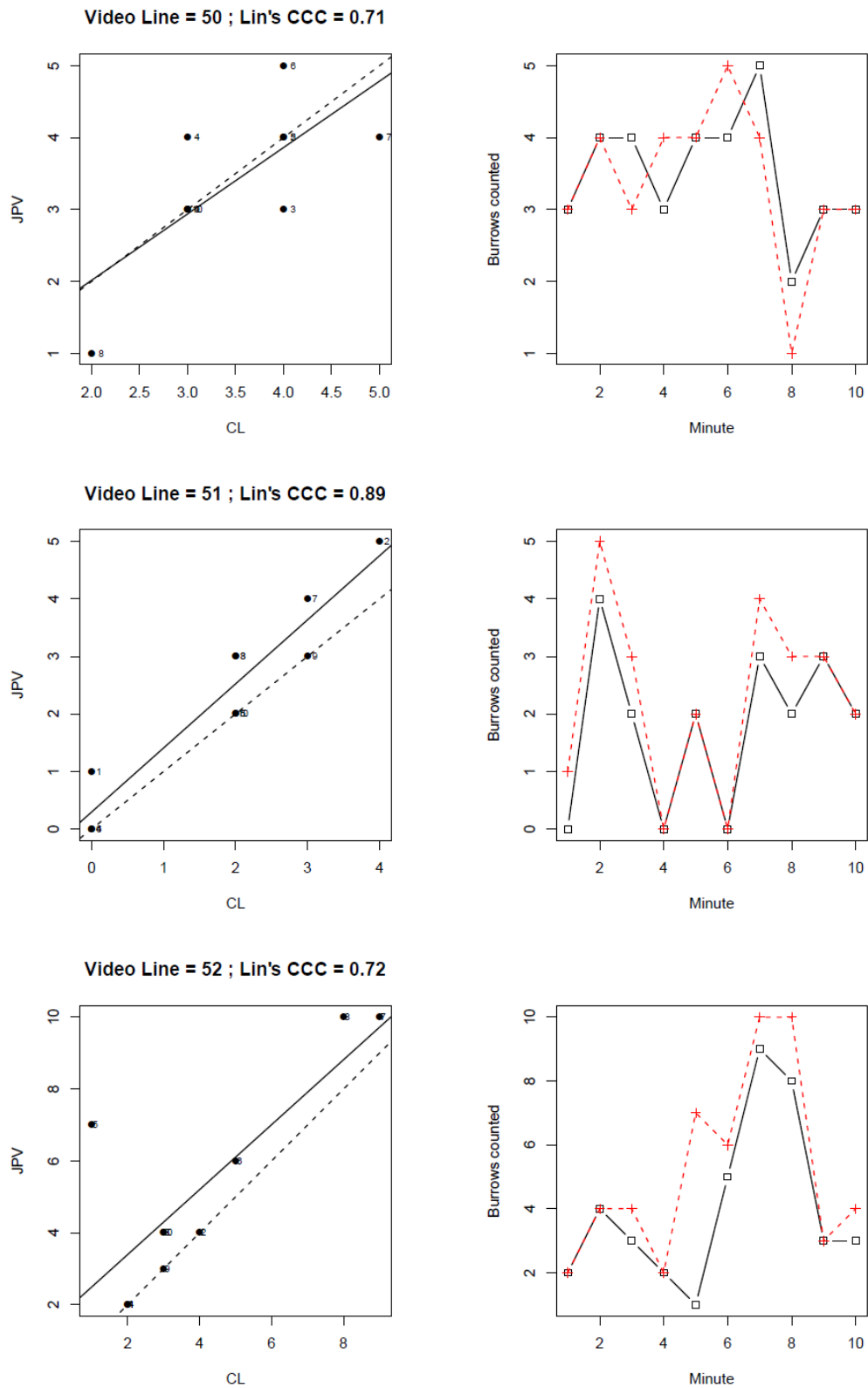


Figure 3: Porcupine Bank 2017. Lin's CCC quality control plot of count data for stations 50 to 52 from the 2017 survey.

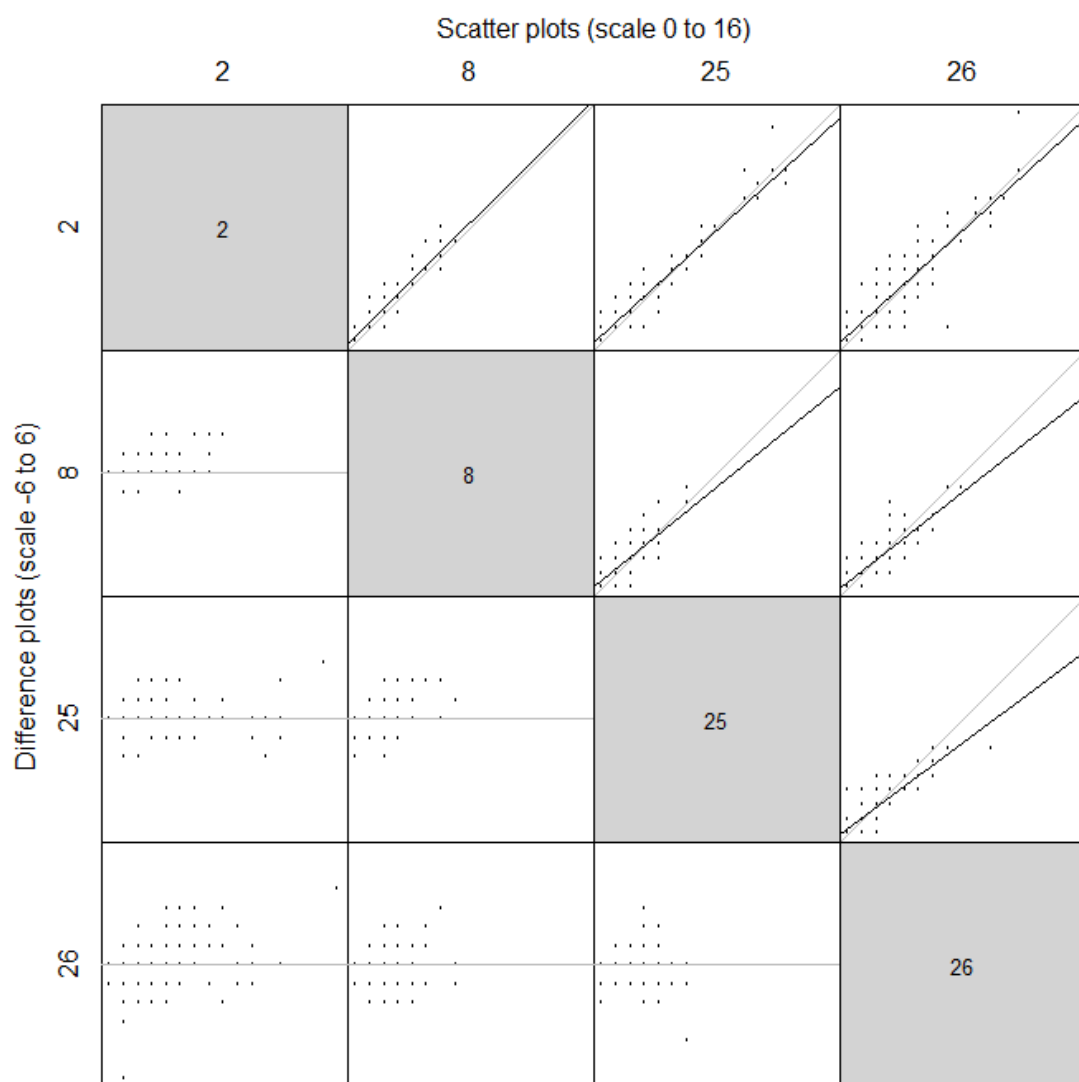


Figure 4. Porcupine Bank 2017. UWTV inter counter comparison plot.

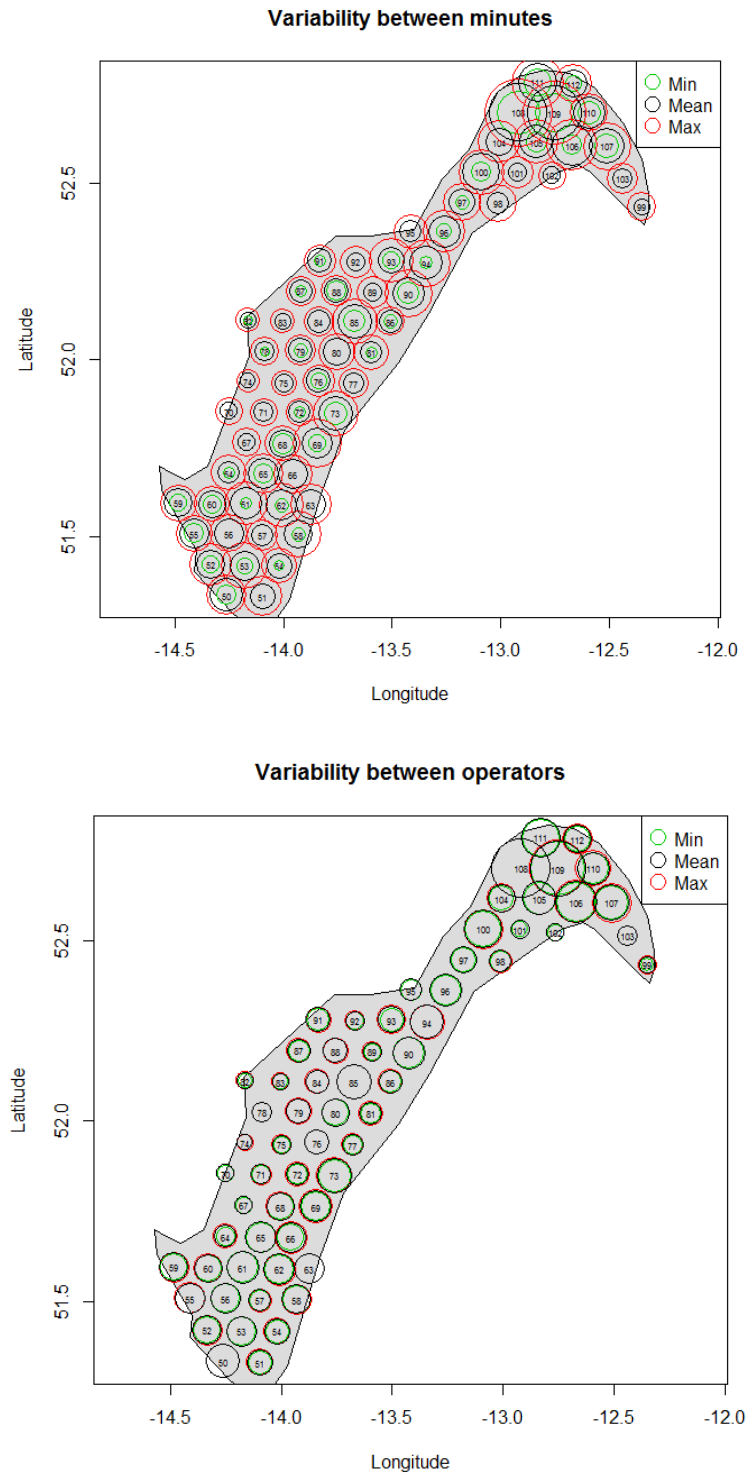


Figure 5. Porcupine Bank 2017. UWTV quality control plot showing variability between minutes (top panel) and between counters (bottom panel) for each UWTV station

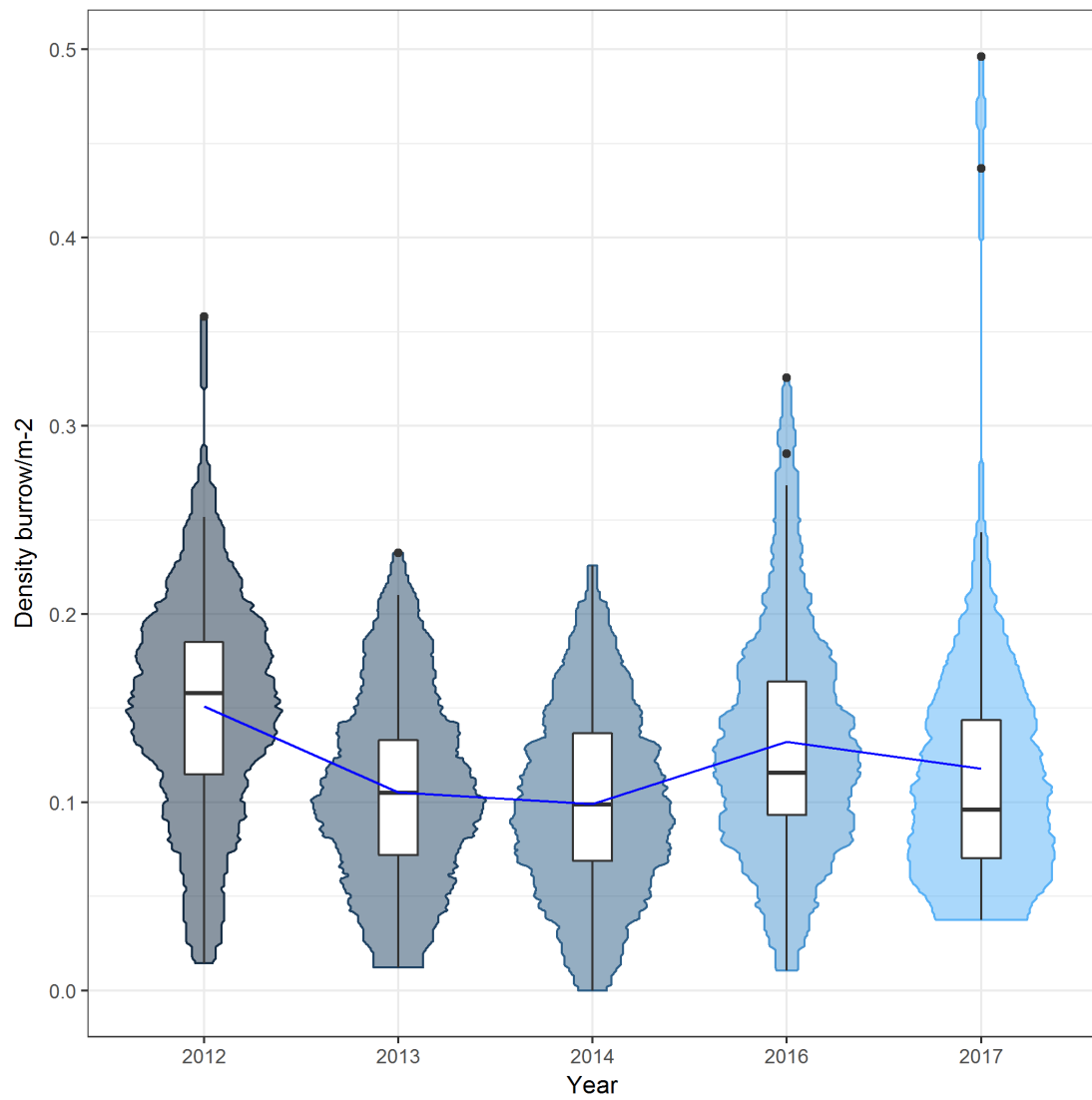


Figure 6. Porcupine Bank 2017. Violin and box plot a of adjusted burrow density distributions by year from 2006-2017. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No UWTV survey in 2015.

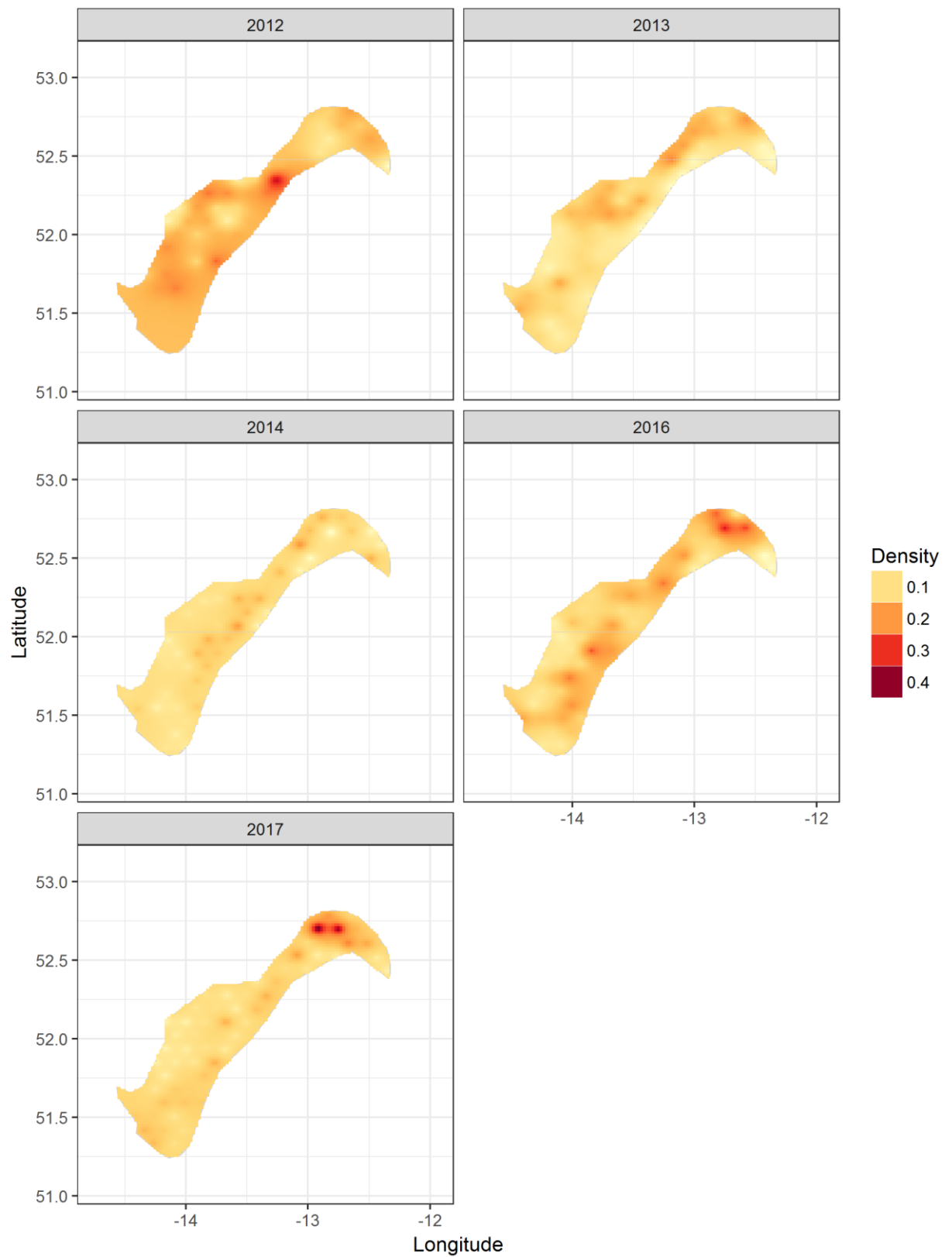


Figure 7. Porcupine Bank UWTV. Heat map of *Nephrops* burrow density observations.

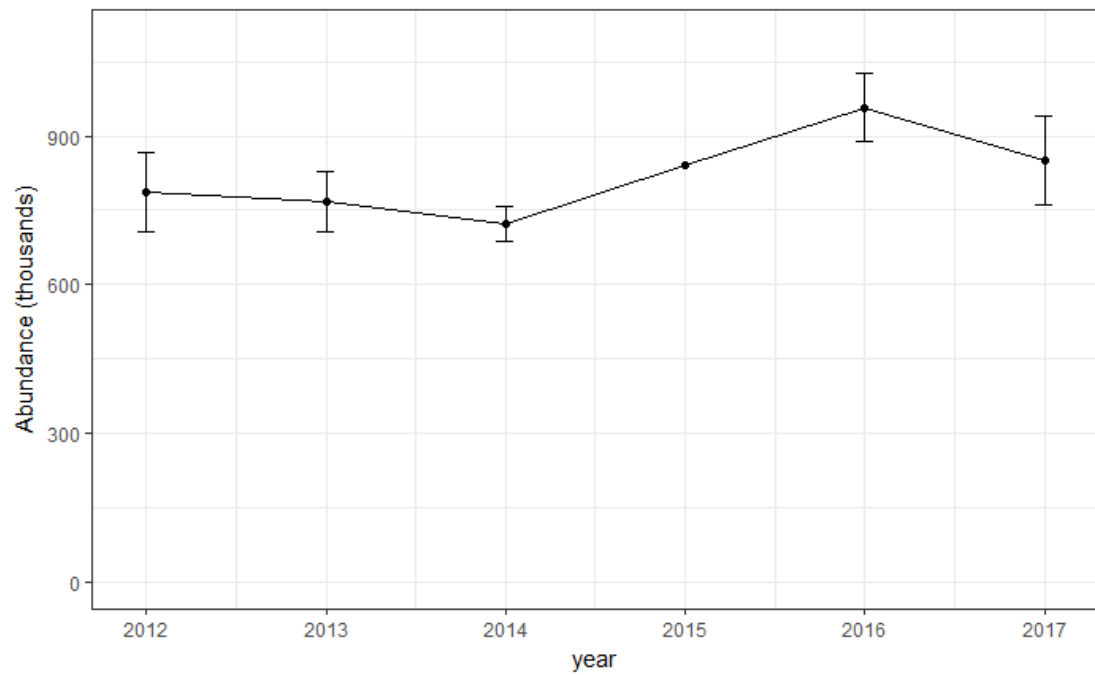


Figure 8. Porcupine Bank UWTV 2017. Time series of total abundance estimates for FU16 (error bars indicate 95% confidence intervals). No UWTV survey in 2015 point is extrapolated.

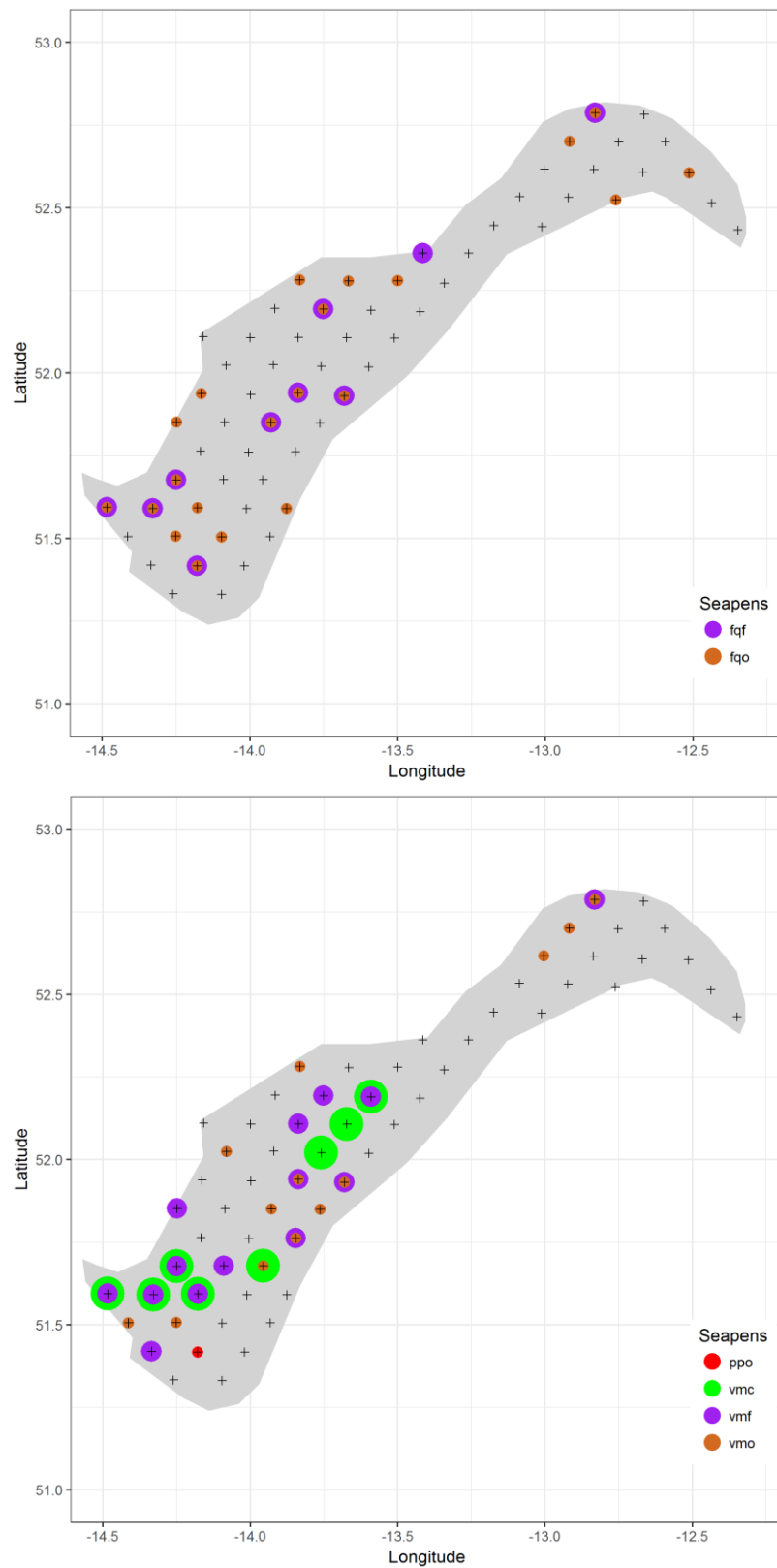


Figure 9. 2017 stations where *Funinculina quadrangularis* (fq top left panel) and *Virgularia mirabilis* and *Pennatula phosphorea* (vm/pp -bottom panel) were identified and classified according to abundance key - occasional (o), frequent (f), common (c). (+) denotes TV stations with no sea-pen observations.

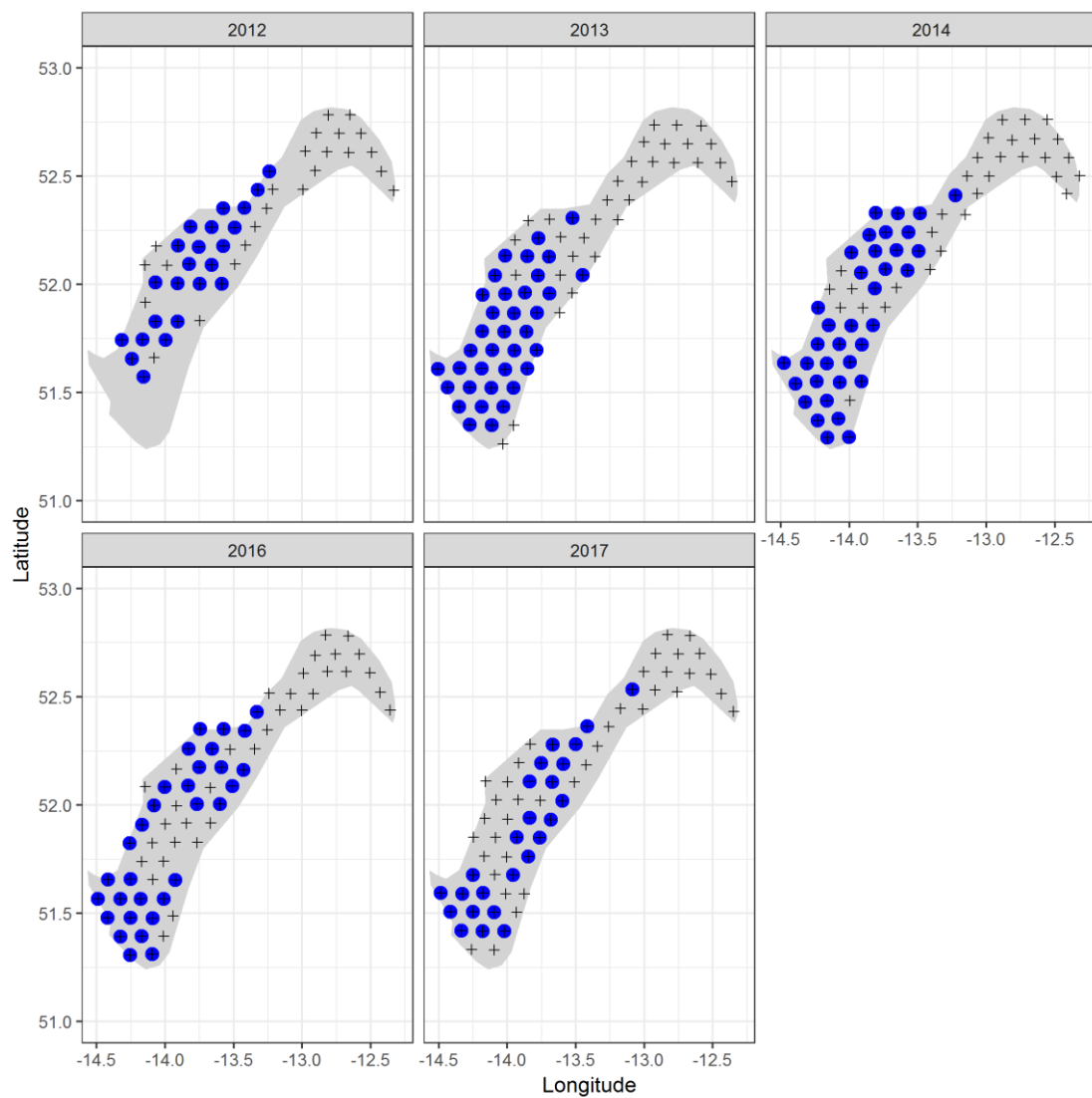


Figure 10. Porcupine Bank UWTV 2017. The presence/absence distribution of the deep water sea-pen species *Kophobelemnion stelliferum* observed on the video footage 2012 to 2017. (+) denotes no observation and blue circle denotes presence. No UWTV survey in 2015.

Table 1. Key for classification of sea-pen abundance as used on Irish UWTV surveys.

Number/Min
Common 20-200
Frequent 2-19
Ocasional <2

Species

Virgularia mirabilis
Pennatula phosphorea
Funiculina quadrangularis

Sea Pens								
<i>V. mirabilis</i>			<i>P. phosphorea</i>			<i>F. quadrangularis</i>		
C	F	O	C	F	O	C	F	O

Table 2. Porcupine Bank *Nephrops*: Summary of univariate statistics and geostatistics for the burrow density estimates (bias corrected) on the Porcupine Bank UWTV survey in 2012-2017. No TV survey in 2015.

Univariate Statistics	2012	2013	2014	2015	2016	2017
Number of Observations	47	68	67		65	63
Minimum:	0.014	0.012	0		0.010	0.037
Maximum:	0.358	0.233	0.226		0.325	0.496
Mean:	0.151	0.106	0.099		0.132	0.118
Standard Deviation:	0.063	0.051	0.049		0.005	0.80
Variance:	0.005	0.003	0.002		0.004	0.006
Geostatistics	2012	2013	2014	2015	2016	2017
Adjusted abundance estimate (millions)	787	768	722		958	850
Domain area (km ²)	7108	7108	7108		7108	7134
Coef. of Variation	0.049	0.044	0.025		0.036	0.054

Table 3. Porcupine Bank *Nephrops*: Inputs to short-term catch option table.

Year	Landing s in number	Total discard s in number *	Removal s in number	UWTV abundanc e estimates	95% conf. interval s	Harves t rate	Mean weight in landings	Mean weight in discards	Discar d rate	Dead discar d rate
	millions	millions	millions	millions	millions	%	gramme s	gramme s	%	%
2012	25	0	25	787	78.7	3.2	50.4	NA	0	0
2013	19.8	0	19.8	768	61.4	2.6	57.5	NA	0	0
2014	17.4	0	17.4	722	35.4	2.4	68.4	NA	0	0
2015	27.4	0	27.4	NA	NA	3.3**	50.9	NA	0	0
2016	53.5	0	53.54	958	68.1	5.6	40.3	NA	0	0
2017				850	89.7					

*Discards are considered negligible and are not included in the assessment.

** The harvest rate is estimated based on a linear extrapolation of abundance for 2015 when no survey was carried out.

Table 4: Porcupine Bank *Nephrops*: The basis for the catch options for 2017.

Variable	Value	Source	Notes
Stock abundance	850	ICES (2017a)	UWTV survey 2017.
Mean weight in landings	51.9	ICES (2017a)	Average 1986–2016.
Mean weight in discards	-	ICES (2017a)	Not relevant.
Discard proportion	-	ICES (2017a)	Discarding is negligible.
Discard survival rate	-	ICES (2017a)	Not relevant.
Dead discard rate	-	ICES (2017a)	Discarding is negligible.

Table 5: Porcupine Bank *Nephrops*: Short-term management option table giving catch options for 2018 using the 2017 UWTV survey estimate.

Basis	Total catches*	Landings	Dead discards**	Surviving discards**	Harvest rate
	L+DD+SD	L	DD	SD	for L+DD
ICES advice basis					
MSY approach; F_{MSY}	2734	2734	0	0	6.2%
Other options					
$F_{2014-16}$	1659	1659	0	0	3.8%
F_{MSY} (lower)	2205	2205	0	0	5.0%

* Total catches are the landings plus dead and surviving discards.

** Based on minimal discarding during observer trips up to 2016.