Porcupine Bank *Nephrops* Grounds (FU16)
2018 UWTV Survey Report and catch scenarios for 2019

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Version October 2018

Ireland's European Structural and Investment Funds Programmes 2014-2020

Co-funded by the Irish Government and the European Union

Department of Agriculture, Food and the Marine

An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

Abstract

This report provides the results of the sixth 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 69 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 2018, adjusted for edge effect, was 0.16 burrows/m². The final krigged abundance estimate was 1117 million burrows with a relative standard error of 4% and an estimated stock area of 7,130 km^2. The 2018 abundance estimate was 31% higher than in 2017. Using the 2018 estimate of abundance and updated stock data implies catch of 2,645 tonnes and landings of 2,645 tonnes in 2019 when MSY approach is applied (assuming that all catch is landed). The three species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangulari*s and *Pennatula phosphorea,* were all observed during the survey. The deepwater sea-pen *Kophobelemnon stelliferum* was also observed and its presence/absence mapped from the available time-series. Trawl marks were also observed on 33% of the stations surveyed.

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

Suggested citation:
Doyle, J., O'Brien, S., Ryan, G., Galligan, S., Hernon, P., Aristegui, M., Vacherot, J.P and Lordan, C. 2018. Porcupine Bank *Nephrops* Grounds (FU16) 2018 UWTV Survey Report and catch scenarios for 2018. Marine Institute UWTV Survey report.

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 2017 Irish landings worth in excess of €54 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, 2018). The total estimated landings in 2017 were 2,154 t which were likely to be worth in the region of €17.8 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 North Western Waters Advisory Council (NWWRAC) and implemented between 1st June and 31st July in 2010-2012. Since 2013 the fishery closed for one month from 01st to 31st of May. Since 2011 a functional unit catch limit (actually landings) has also been 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 advised for a closure of the fishery in 2009 and 2010. The stock situation is known to have improved since 2010 following 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 scenarios and advice for this stock (ICES, 2013).

This was the sixth UWTV survey of the Porcupine Bank *Nephrops* grounds (FU16). The survey was multi-disciplinary in nature and also covered TV stations in FU17, the results of which are presented elsewhere (Doyle *et. al*, 2018).

The specific objectives are listed below:

1. To obtain 2018 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 2018 survey and also documents other data collected during the survey. Operational survey details are available in the form of a survey narrative from the scientist in charge (JD). The 2018 abundance data are used to generate catch options for 2019 in line with the recommendations and procedures outlined at the 2013 ICES benchmark (ICES, 2013) and in stock annex (ICES, 2018) and using the F_{msy} reference points proposed by FMSYREF4 (ICES, 2016).

Material and methods

A randomised isometric gird 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 the Workshop on the use of UWTV surveys for determining abundance in *Nephrops* stocks throughout European waters (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 recommendations of the Study Group on *Nephrops* Surveys (SGNEPS, ICES, 2009b) 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 and also back in the laboratory. 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 and a key was devised to categorise the densities of sea-pens based on a 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 the data quality of navigation, speed, visual clarity and consistency in counts to be checked (an example is given in Figure 2).

In 2018 each burrow was time stamped and agreed by counters. Figure 3 shows this agreement on the Lin's CCC plots, and Figure 4 shows there were no discrepancies between counters. Consistency between counters was very high reflecting the fact that burrow identification was relatively easy.

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 for each station. These show that the variability between minutes was high reflecting the patchy, low density.

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) in "R" 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, a krigged grid file was created using all data points as neighbours, the same boundary used to estimate the domain area, the mean density, total burrow abundance and survey precision calculated.

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 tow.

Results

In 2018 69 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 ranges are also similar. The mean burrow density observed in 2018, adjusted[1] for edge effect, was 0.156 burrows/m². The range of the observations was relatively high from 0.01-0.52 burrows/m².

The final modelled density surfaces from 2012 to 2014 and 2016 to 2018 are shown as a heat maps and bubble plots in Figure 7. The 2018 burrow surface shows an area of higher density in the north and central of the ground. The abundance estimate derived from the krigged burrow surfaces (and adjusted for edge effect) increased by 31% from 850 million burrows in 2017 to 1117 million in 2018 (Figure 8 and Table 2) with an estimated area of the ground or domain area of 7,130 km². The estimation CV on the abundance was around 4.2% in 2018.

Trawl marks were observed at 33% of surveyed stations and 4% 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 2018 survey. The presence/absence of the sea-pen *Kophobelemnon 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 in that year. The catch and landings options at various different fishing mortalities are calculated in line with the stock annex using the 2018 survey abundance are presented in Table 5.

Discussion

This was the sixth systematic UWTV *Nephrops* survey of the Porcupine Bank. The distance from shore (~ 120 nautical miles), exposed nature of the area, the significant

[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).

water depths involved (340-576m) 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 pre-planned survey legs (12, 11 and 10 days). Priority was given to the Porcupine Bank which was successfully completed on the first leg in 2018. 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 2018 all burrows included in the analysis were individually time stamped in the UWTV footage. The large abundance increase in 2018 is likely to be related to a strong recruitment event. The size of *Nephrops* burrows is not quantified in the TV surveys, but burrow counters participating in this survey reported a large number of small burrows in FU16.

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. Catch scenarios for 2019 have been calculated using updated landings mean weight data from WGCSE (ICES, 2018). These data are estimated using the graded landings information for the fishing industry and sampling data carried out at sea by scientific observer. An average over the last three years (2016-2018) to account for the reduced mean weight in the landings estimated in the recent past. The resulting catch advice for 2019 fishing at the F_{msy} point is a slight decrease (-3%) on 2018, mainly due to the decreased mean weight used compared to last year. Carrying out annual UWTV surveys to generate catch advice, while challenging, should be continued annually 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 sea-pen species which occur on mud habitat around Ireland are found on the Porcupine Bank. The occurrence of *Funiculina quadrangularis* in particular is significant owing to its particularly vulnerability to trawl mortality. *F. 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 33% 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.

Acknowledgments

We would like to express our thanks and gratitude to Philip Baugh (Master) and crew of the RV. Celtic Voyager for their good will and professionalism throughout the survey. Thanks also to Marc O'Connor P&O Maritime IT & Instrumentation Technician, for handling all onboard technical difficulties. Thanks to Aodhan Fitzgerald, Rosemarie

Butler (RVOPs) and Rob Bunn and Dave Tully (FEAS) at the Marine Institute for organising survey logistics. Thanks to Gordon Furey, Barry Kavanagh, John Barry and Tom O'Leary P&O Maritime for shore side support.

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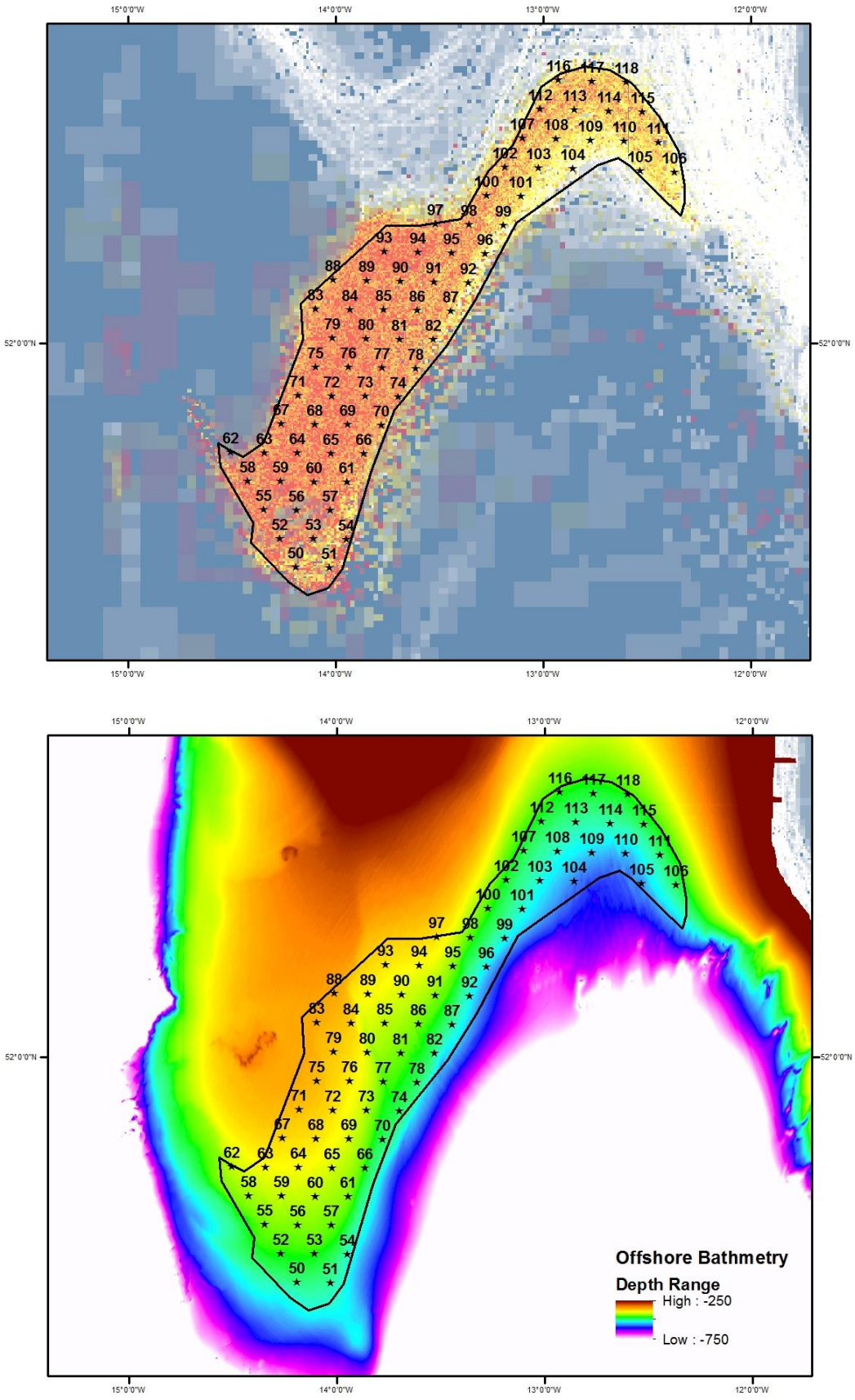

Figure 1. Porcupine Bank 2017. UWTV map of station positions overlaid on a heat map of *Nephrops* directed fishing (top panel) and bathymetry (bottom panel). The black polygon line indicates the ground boundary currently used.

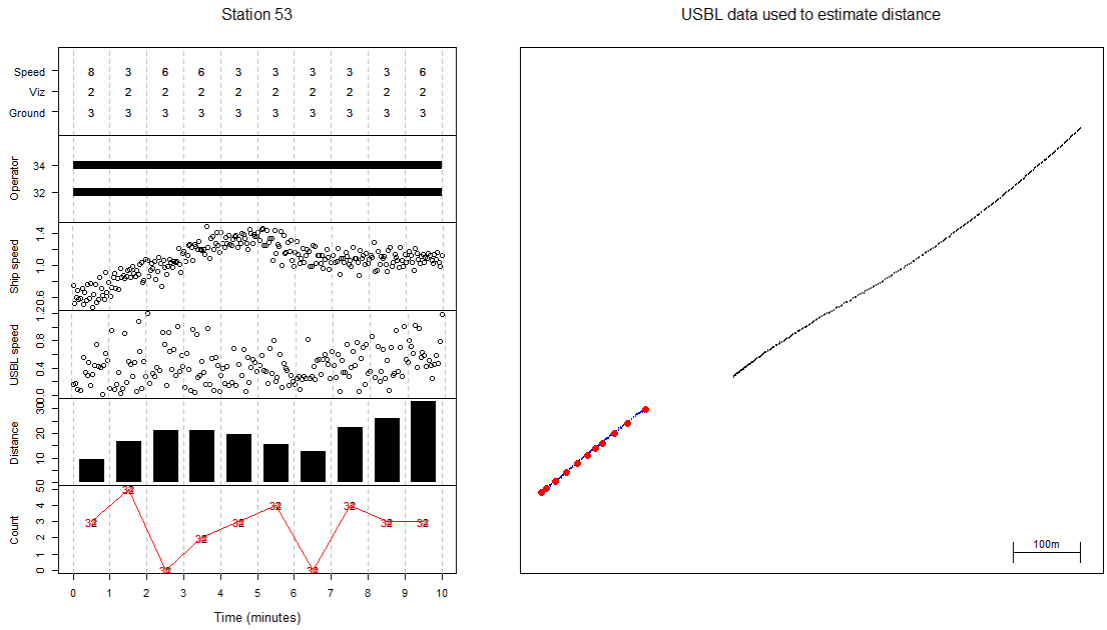

Figure 2. Porcupine Bank 2018. UWTV example quality control plot for the navigational and recount data.

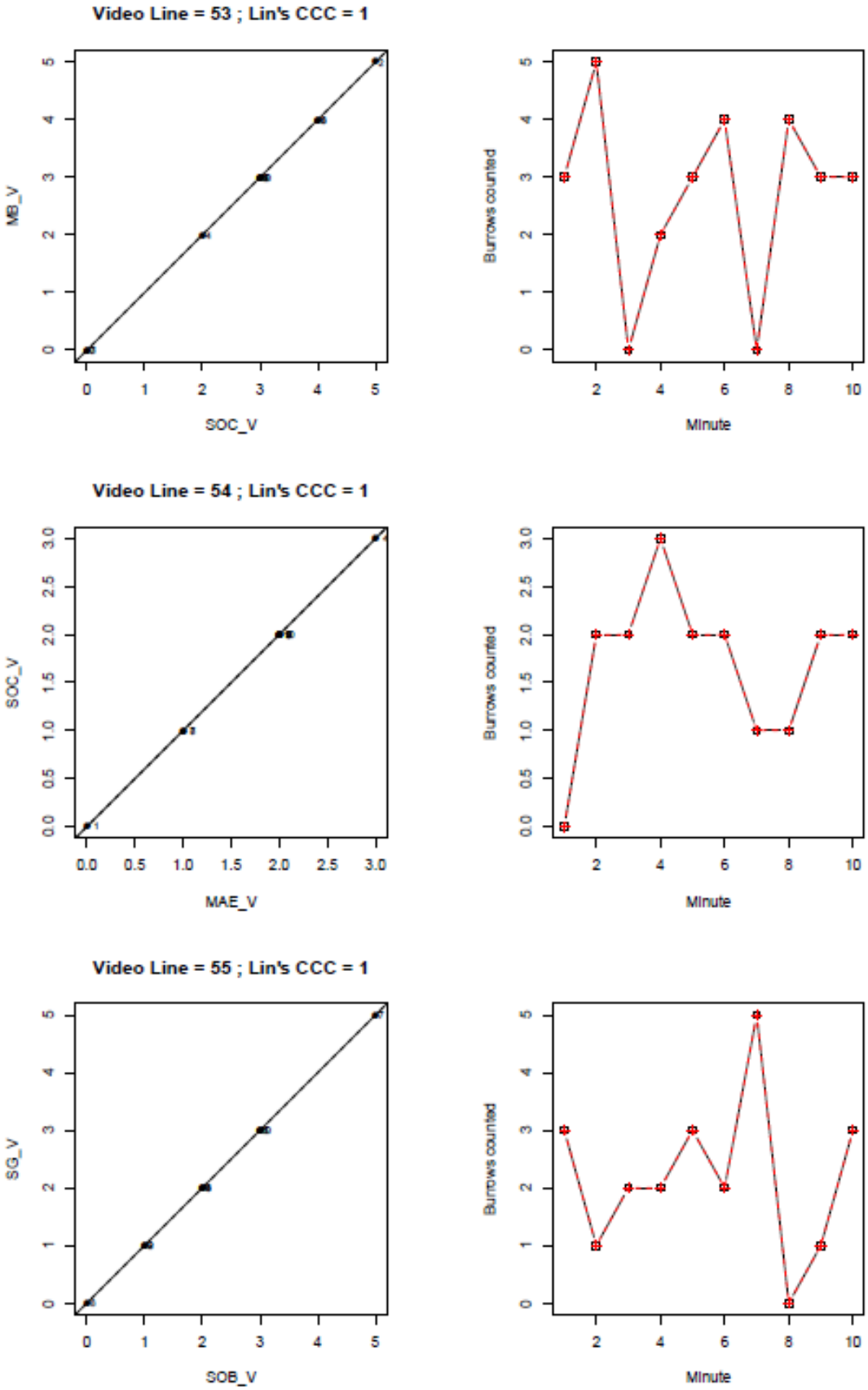

Figure 3: Porcupine Bank 2018. Lin's CCC quality control plot of count data for stations 53 to 55 from the 2018 survey.

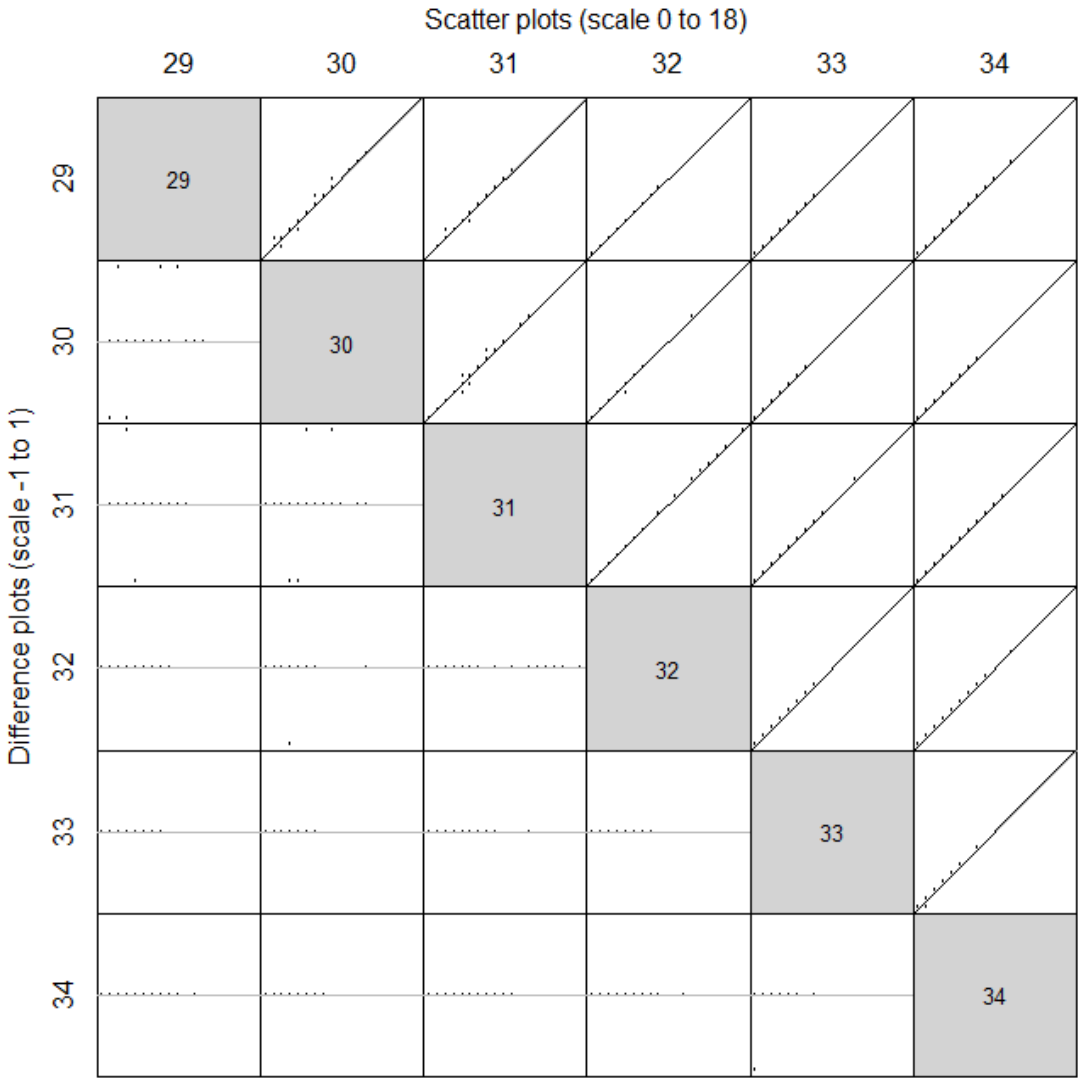

Figure 4. Porcupine Bank 2018. UWTV inter counter comparison plot.

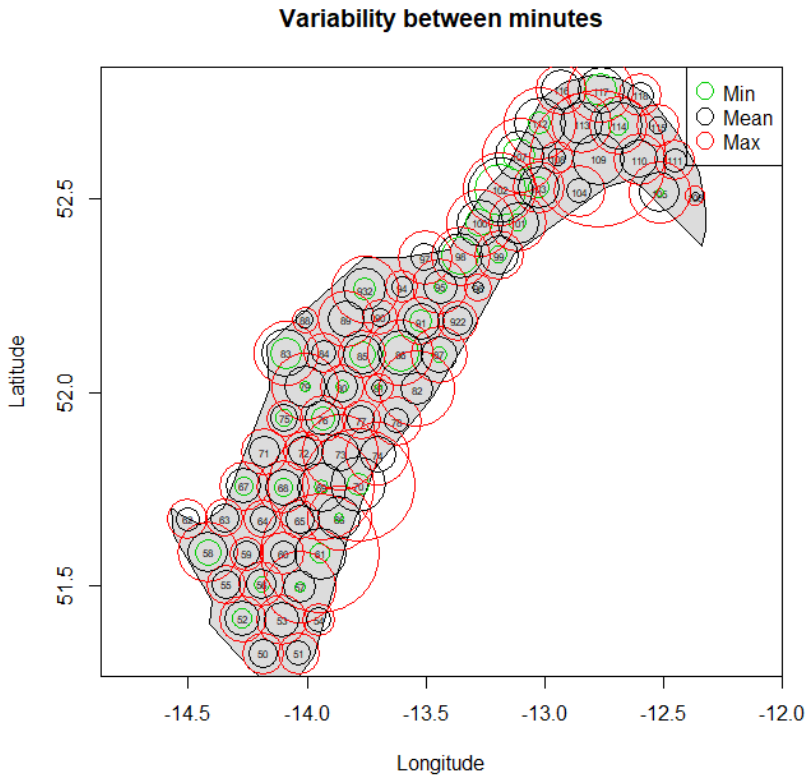

Figure 5. Porcupine Bank 2018. UWTV quality control plot showing variability between minutes (top panel) for each UWTV station

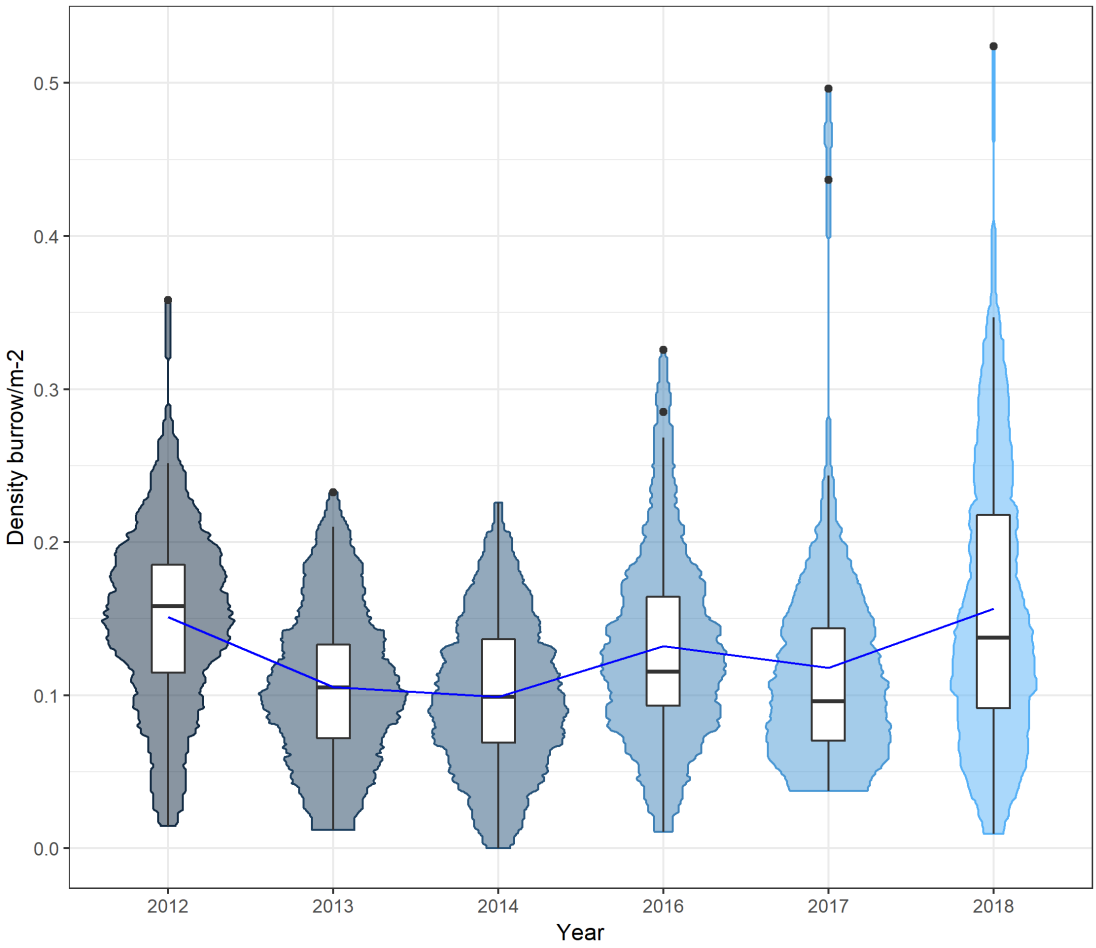

Figure 6. Porcupine Bank 2018. Violin and box plot a of adjusted burrow density distributions by year from 2012-2018. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No UWTV survey in 2015.

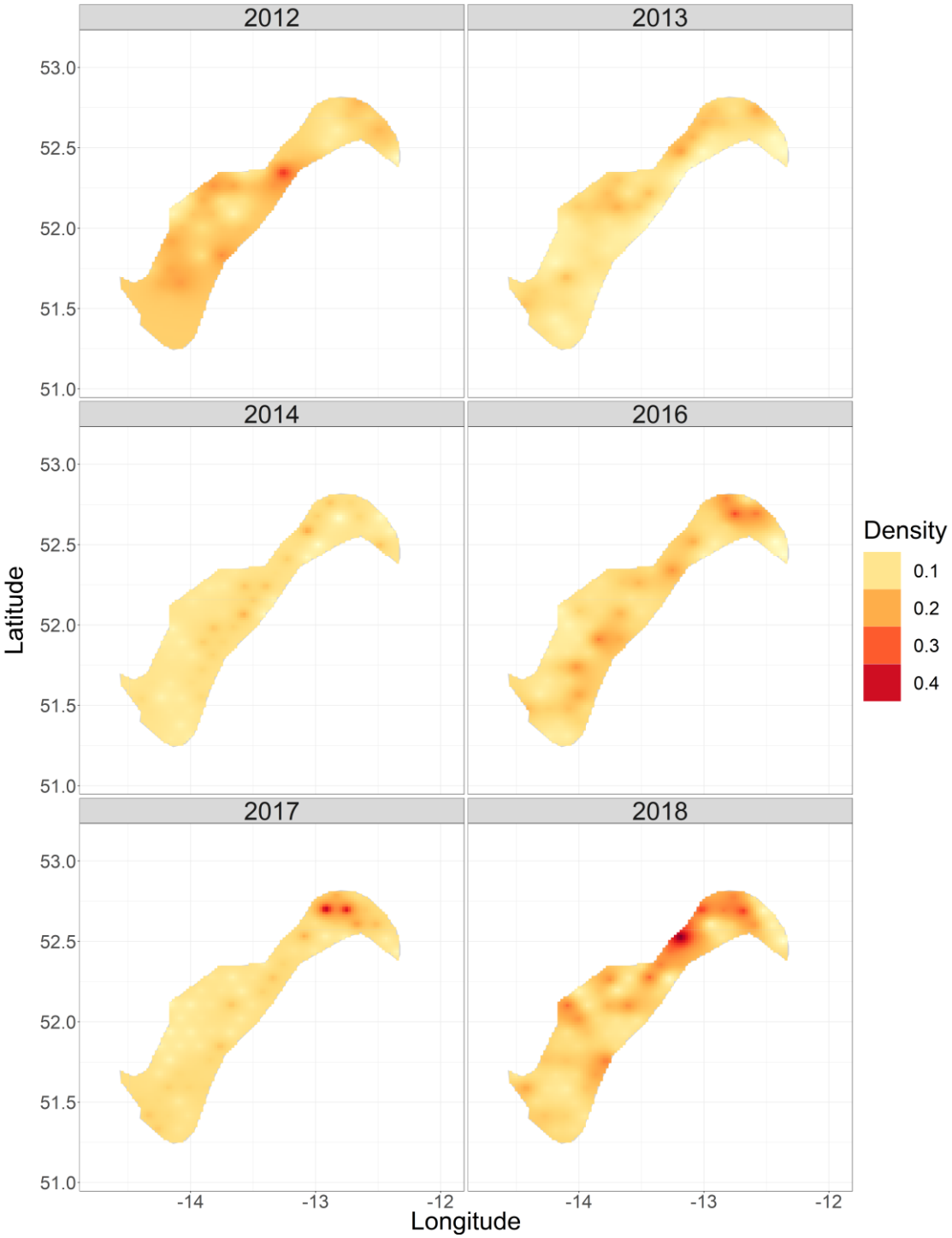

Figure 7. Porcupine Bank UWTV. Heat map of *Nephrops* burrow density observations.

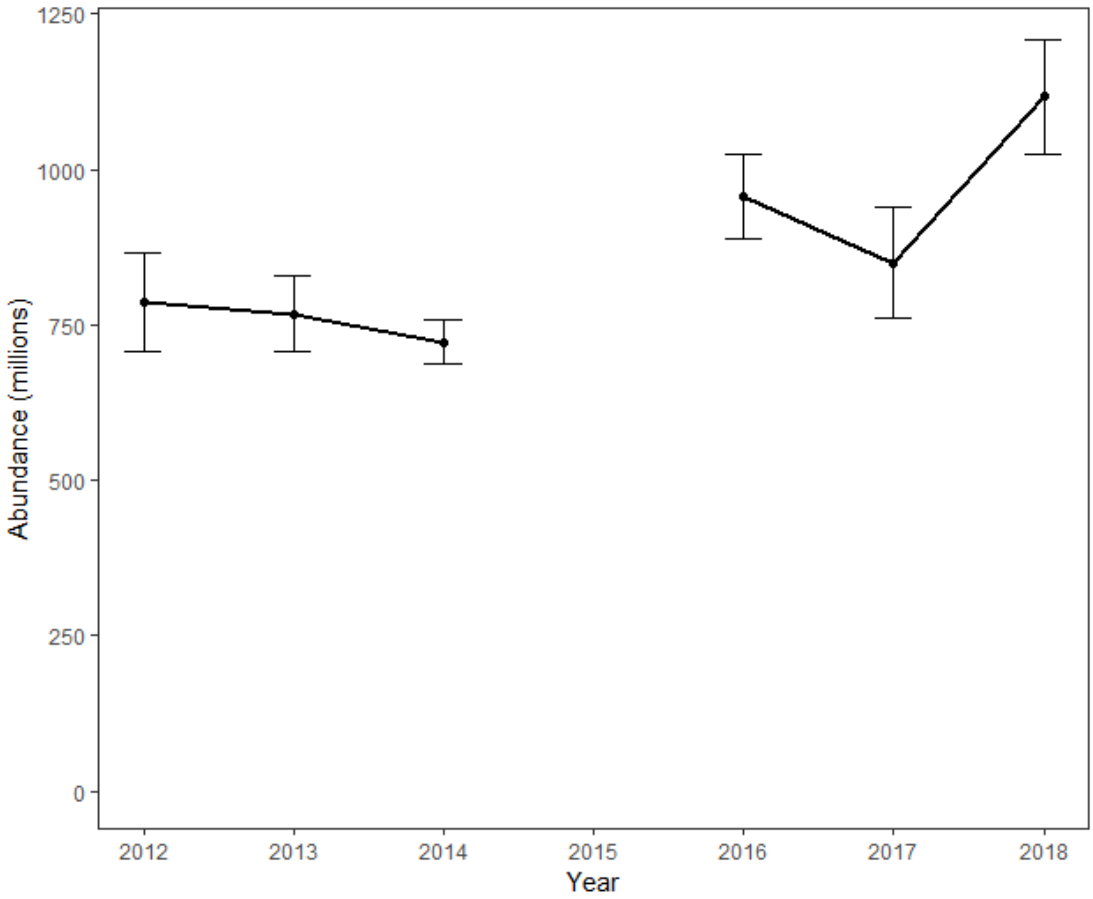

Figure 8. Porcupine Bank UWTV 2018. Time series of total abundance estimates for FU16 (error bars indicate 95% confidence intervals). No UWTV survey in 2015.

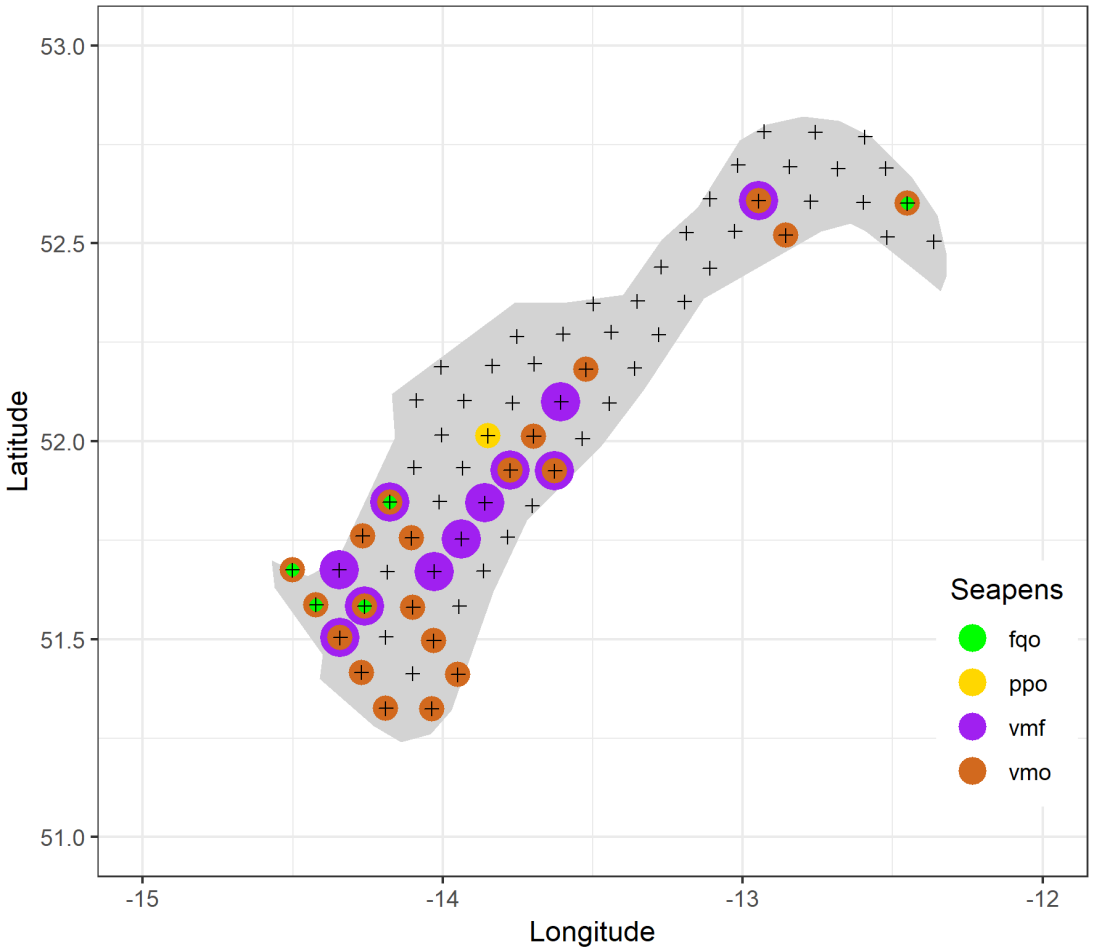

Figure 9. 2018 stations where *Funiculina quadrangularis* (fq), *Virgularia mirabilis* (vm) and *Pennatula phosphorea* (pp) were identified and classified according to abundance key - occasional (o), frequent (f). Single (+) denotes TV stations with no sea-pen observations.

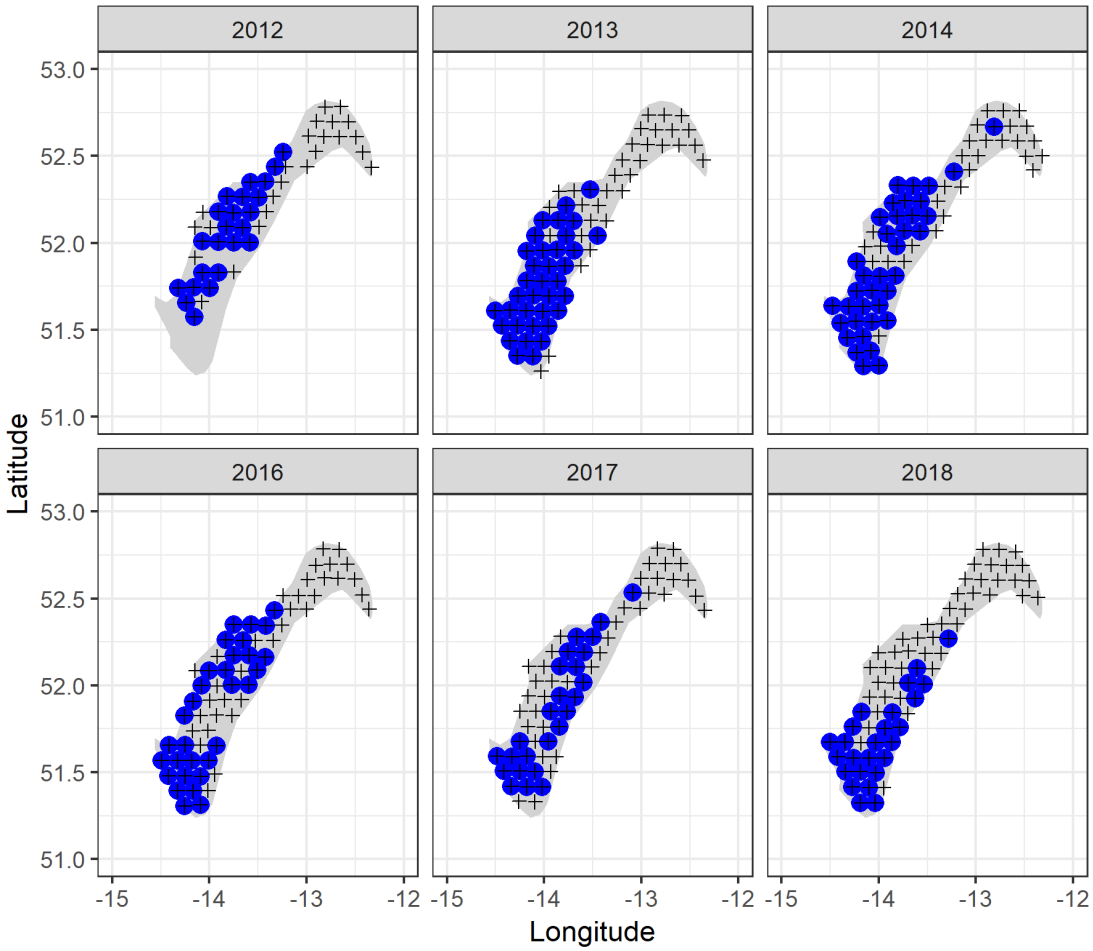

Figure 10. Porcupine Bank UWTV 2018. The presence/absence distribution of the deep water sea-pen species *Kophobelemnon stelliferum* observed on the video footage 2012 to 2018. Single (+) denotes no observation and blue circle denotes presence. No UWTV survey in 2015.

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								
V. mirabilis			*P. phosphorea*			*F. quadrangularis*		
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 2012-2018. No TV survey in 2015.

	Univariate Statistics						**Geostatistics**		
Year	Number of Observations	Min	Max	Mean	Standard Deviation	Variance	Adjusted abundance estimate (millions)	Domain area (km^2)	Coef. Of Variation
2012	47	0.014	0.358	0.151	0.063	0.005	787	7108	0.049
2013	68	0.012	0.233	0.106	0.051	0.003	768	7108	0.044
2014	67	0	0.226	0.099	0.049	0.002	722	7108	0.025
2015	0								
2016	65	0.01	0.325	0.132	0.005	0.004	958	7108	0.036
2017	63	0.037	0.496	0.118	0.8	0.006	850	7134	0.054
2018	69	0.01	0.524	0.156	0.011	0.009	1117	7130	0.042

Table 3. Porcupine Bank *Nephrops*: Inputs to catch scenarios table.

Year	Landings in number	Total discards in number *	Removals in number	UWTV abundance estimates	95% conf. intervals	Harvest rate	Mean weight in landings	Mean weight in discards	Discard rate	Dead discard rate
	millions	millions	millions	millions	millions	%	grammes	grammes	%	%
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	69.5	0	69.5	850	89.7	8.2	30.7	NA	0	0
2018				1117	91.6		43.3			

*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 advice and scenarios.

Variable	Value	Notes
Stock abundance (2019)	1117 million individuals	UWTV survey 2018 (number of individuals)
Mean weight in wanted catch	38.2 g	Average 2016–2018.
Mean weight in unwanted catch	-	Unknown.
Unwanted catch	-	Discarding is assumed negligible.
Discards survival	-	Not applicable
Dead unwanted catch	-	Assumed to be zero.

Table 5: Porcupine Bank *Nephrops:* Annual catch advice and scenarios;

Basis	Total catch	Dead removals	Wanted catch*	Dead unwanted catch	Surviving unwanted catch	Harvest rate* %	% advice change **
	WC+DUC+SUC	WC+DUC	WC	DUC	SUC	for WC+DUC	
ICES advice basis							
MSY approach	2645	2645	2645	0	0	6.2	-3
Other Scenarios							
$F_{MSY\ lower}$	2133	2133	2133	0	0	5.0	-22
$F_{MSY\ upper}$	2645	2645	2645	0	0	6.2	-3
F_{2017}	4262	4262	4262	0	0	10.0	56

* Calculated for dead removals and applied to total catch.

** Advice value 2019 relative to advice value 2018.