Porcupine Bank *Nephrops* Grounds (FU16)
2019 UWTV Survey Report and catch scenarios for 2020

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Abstract

This report provides the results of the seventh 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 65 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 2019, adjusted for edge effect, was 0.14 burrows/m². The final krigged abundance estimate was 1010 million burrows with a relative standard error of 5% and an estimated stock area of 7,130 km^2. The 2019 abundance estimate was 9.5% lower than in 2018. Using the 2019 estimate of abundance and updated stock data implies catches between 2127 and 2637 tonnes in 2020 that correspond to the F ranges in the EU multi annual plan for Western Waters (assuming that all catch is landed). Four species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangularis*, *Pennatula phosphorea* and the deepwater sea-pen *Kophobelemnon stelliferum* were observed during the survey. Trawl marks were also observed on 31% of the stations surveyed.

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

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Introduction

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 Irish landings in 2018 worth around €56 million at first sale. The *Nephrops* fishery on the Porcupine Bank takes place on a large area approximately 7,130 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 2018 were 2,079 t which were likely to be worth €20 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 seventh UWTV survey of the Porcupine Bank *Nephrops* grounds (FU16). The 2019 survey was multi-disciplinary in nature and also covered TV stations in FU2021; The specific objectives are listed below:

1. To obtain 2019 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 presence 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 2019 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 (MA). The 2019 abundance data are used to generate catch options for 2020 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 in 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 341-569 m in depth with an average depth of 451 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. In 2019, due to weather conditions in mid-June, the FU16 survey was postponed and carried out between June 23rd and July 3rd on RV Celtic Voyager.

In 2019 image data was collected by a custom built camera system recording High Definition still image data at 12 frames per second with a camera angle of 75°. The digital images were stored on a server and were reviewed onboard through an inhouse developed Image annotation R Shiny app (Aristegui, 2019). This application allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner. The survey process onboard is now paperless.

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. Time referenced high definition image data was collected with a field of view or 'FOV' of 1.01 metre. 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 for 98% all of stations. For one station corrected ship navigation data was used.

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.

Presence / absence notes were also recorded each station on the occurrence of trawl marks, fish and other species. Presence / absence of sea-pen species were also recorded to fulfil an 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 the data quality of navigation, speed, visual clarity and consistency in counts to be checked (an example is given in Figure 2).

In 2019 the survey count data were 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). Lin's CCC quality control plot of survey count data for stations 60 to 62 is shown in Figure 3. When the count data fell below the threshold of 0.6 a third review was carried out. The paired count data that passed the Lin's CCC threshold was used in the analysis. When the paired counts did not pass the threshold an average of the three reviewers was deemed appropriate to use in the analysis.

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. In 2019 the field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.01 m assuming that the sledge was flat on the seabed (i.e. no sinking). The burrow systems in this area are relatively large and occurred at low density making the verification recounts 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) 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.

For each UWTV station a temperature and depth profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE39plus. This data will be processed at a later stage.

Results

In 2019 65 stations were completed successfully on the Porcupine Bank. Figure 4 shows bubble plots of the variability between minutes for each station. At the lower densities observed the relative scale of variation between minutes was higher than typical in other areas, reflecting the patchy and low density.

A combined violin and box plot of the observed burrow densities is presented in Figure 5. 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 2019, adjusted[1] for edge effect, was 0.14 burrows/m².

The final modelled density surfaces from 2012 to 2014 and 2016 to 2019 are shown as a heat map in Figure 6. The 2019 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 9.5% from 1117 million burrows in 2018 to 1010 million in 2019 (Figure 7 and Table 1) with an estimated area of the ground or domain area of 7,131 km². The estimation CV on the abundance was around 5.1% in 2019.

Trawl marks were observed at 31% of surveyed stations. The distribution of the various sea-pen species observed on the UWTV footage is shown in Figure 8. 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 2019 survey. The distribution over time of a fourth sea-pen, *Kophobelemnon stelliferum*, is shown in Figure 9 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 2). The basis to the catch options table is given in Table 3. The harvest rate (calculated as (landings + dead discards)/(abundance estimate)) is based on a linear extrapolation of abundance for

[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).

2015 as no TV survey was carried out in that year. The catch and landings options calculated using the 2019 survey abundance estimate and updated stock data (in line with the stock annex), imply catches between 2127 and 2637 tonnes in 2020 that correspond to the F ranges in the EU multi annual plan for Western Waters, assuming that discard rates and fishery selection patterns do not change from the average of 2016–2018 (Table 4).

Discussion

This was the seventh 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 (341-569m) 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 second leg in 2019, after moving the first leg to other FUs due to weather conditions. 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 2019 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 decreased. Catch scenarios for 2020 have been calculated using updated landings mean weight data from WGCSE (ICES, 2019). 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 2020 fishing at the F_{msy} point is a decrease (-9.5%), mainly due to the decreased abundance estimate 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 *F. 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 31% 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 Colin McBrearty (Master) and crew of the RV. Celtic Voyager for their good will and professionalism throughout the survey. Thanks to the onboard P&O technician Tim O'Sullivan who maintained the UWTV system throughout the survey. Thanks to Aodhan Fitzgerald, Rosemarie Butler and Tricia McManus (RVOPs) and Rob Bunn and Dave Tully (FEAS) at the Marine Institute for organising survey logistics, and also Gordon Furey and Damian Crean (P&O Maritime) for shore side support.

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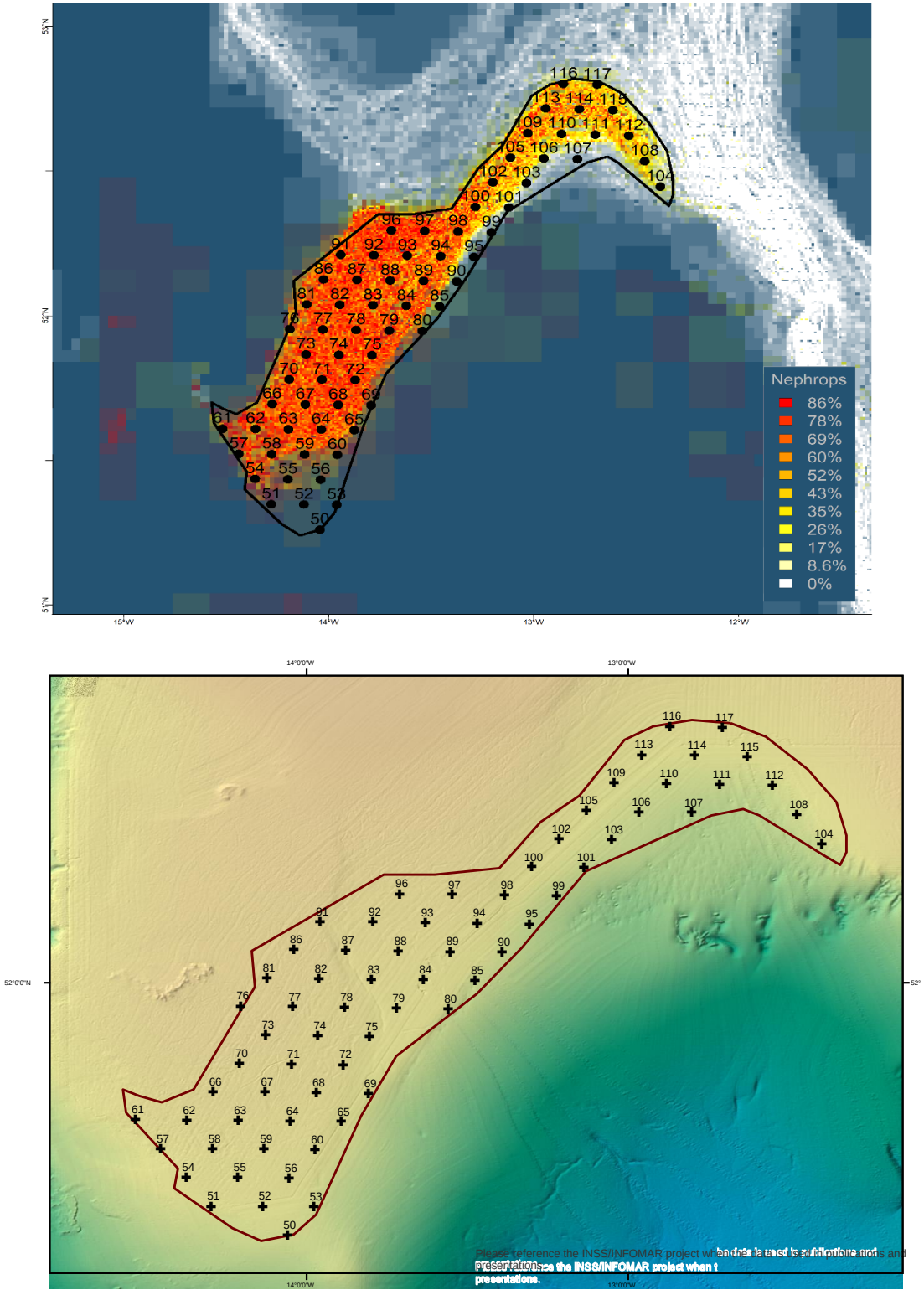

Figure 1: FU16 UWTV 2019. UWTV map of station positions overlaid on a heat map of *Nephrops* directed fishing (top panel) and bathymetry (bottom panel). The black polygon line indicates the ground boundary currently used.

Source: INFOMAR is the Department of Communications, Climate Action and Environment (DCCAE) funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and Marine Institute

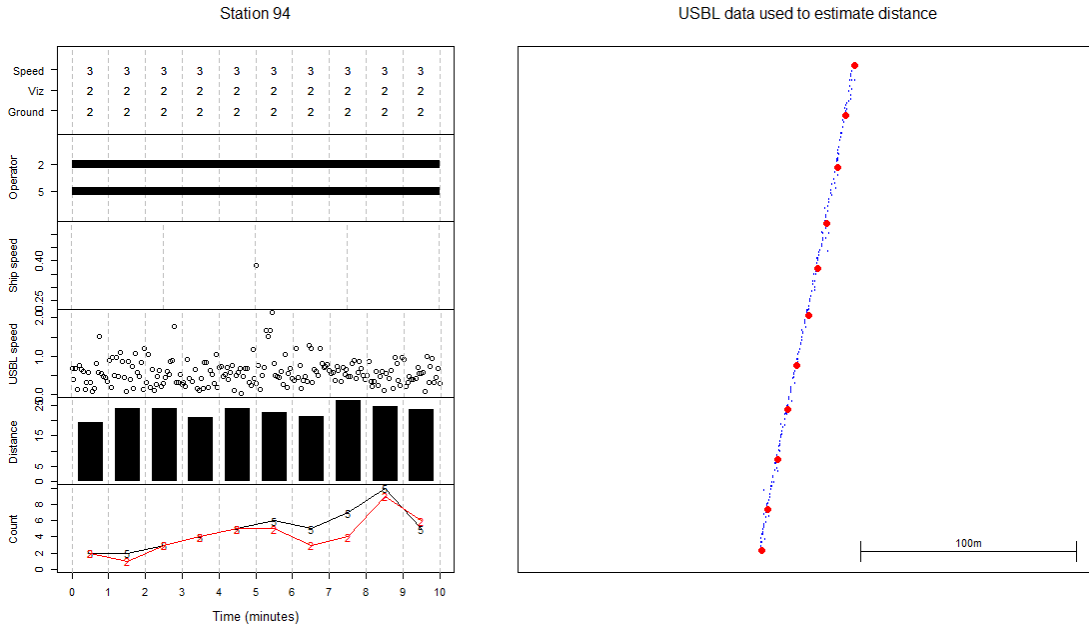

Figure 2: FU16 UWTV 2019. UWTV example quality control plot for the navigational and recount data.

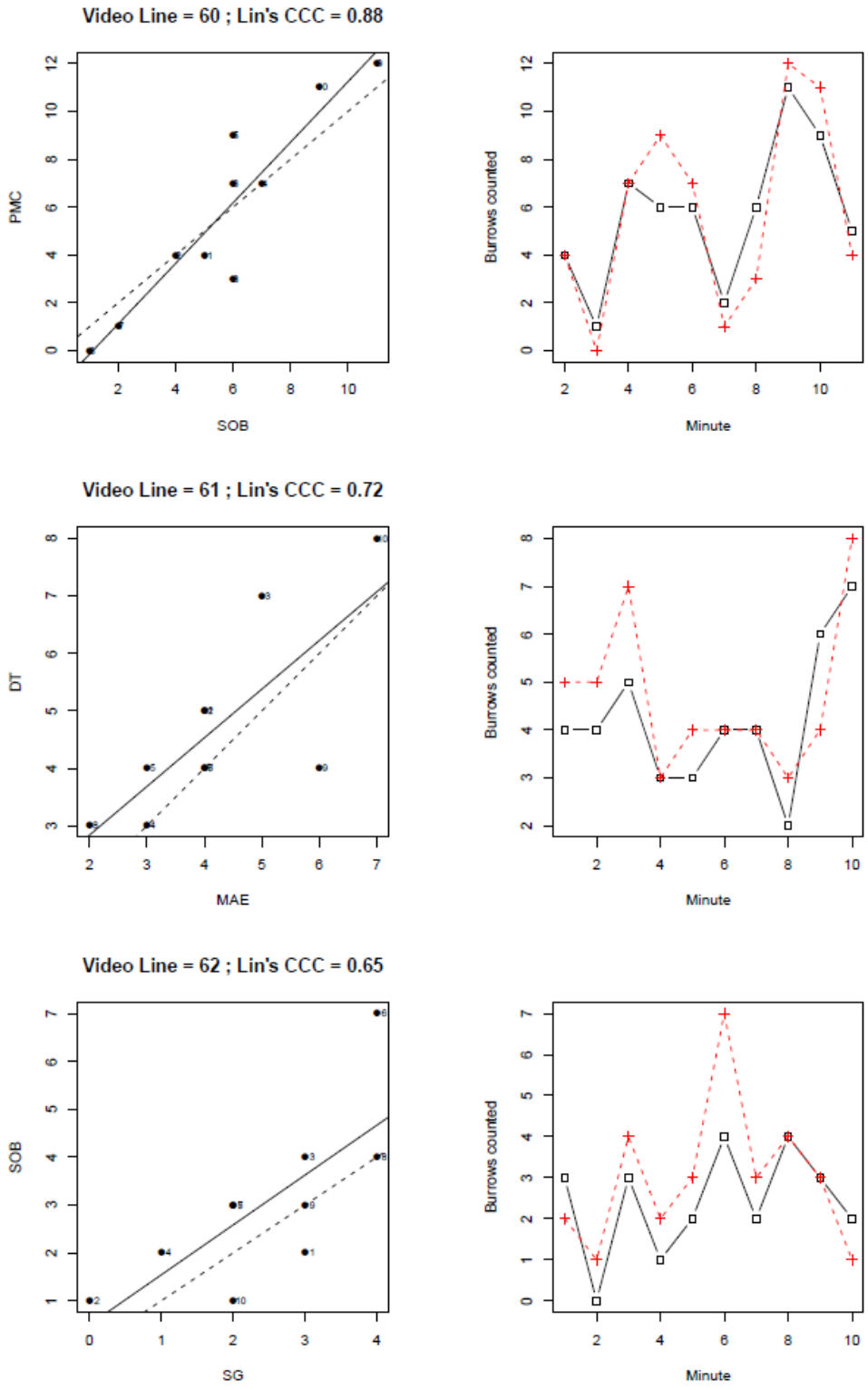

Figure 3: FU16 UWTV 2019. Lin's CCC quality control plot of count data for stations 60 to 62 from the 2019 survey.

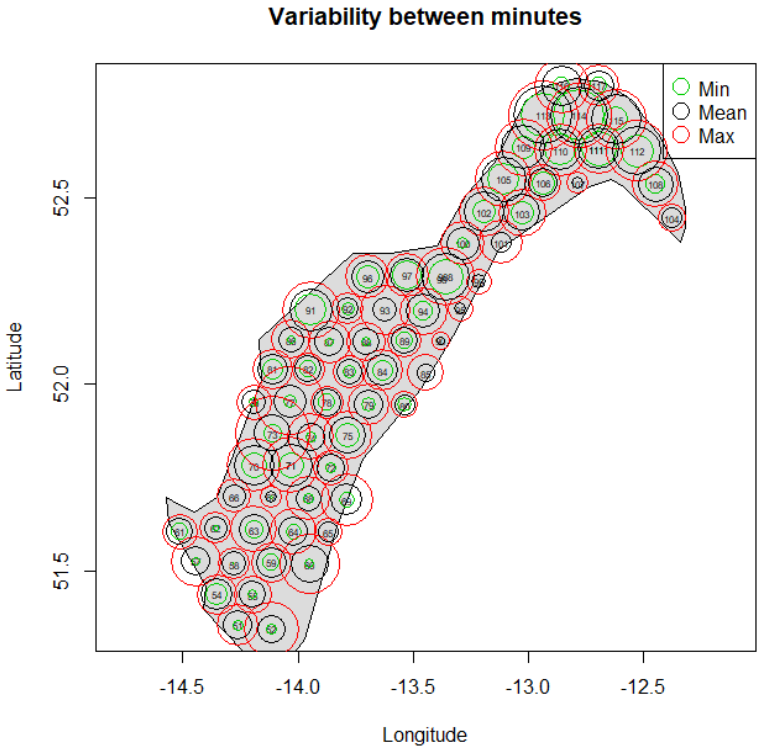

Figure 4: FU16 UWTV 2019. UWTV quality control plot showing variability between minutes for each UWTV station

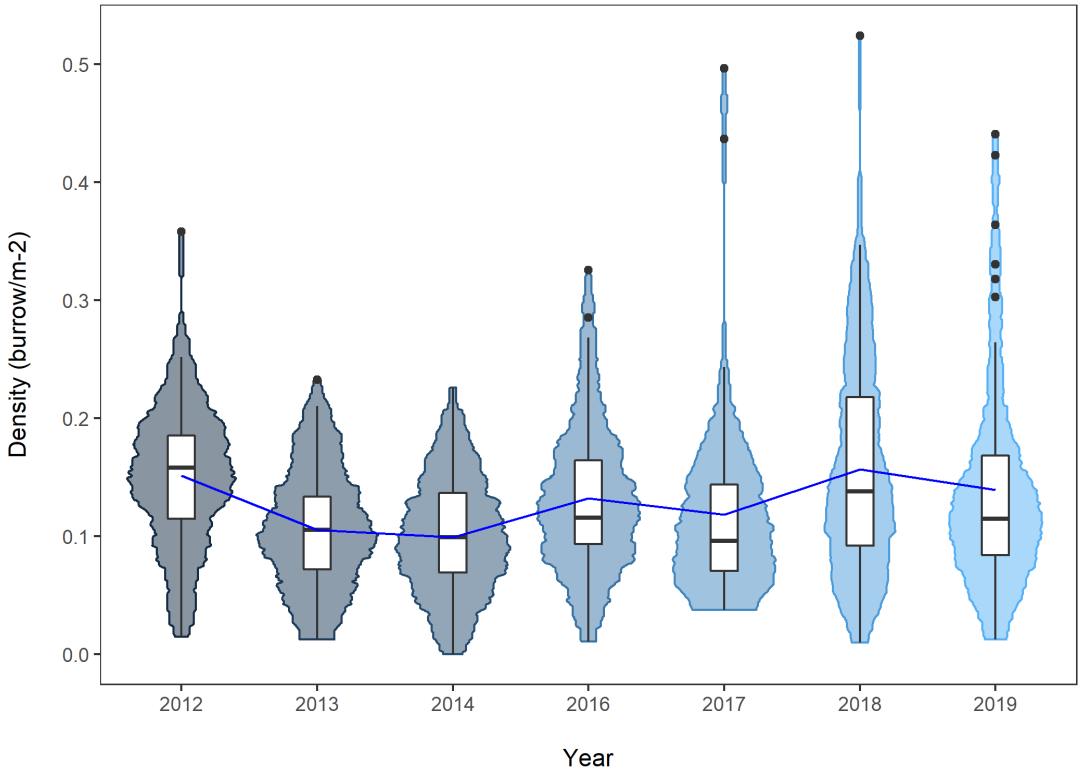

Figure 5: FU16 UWTV 2019. Violin and box plot of adjusted burrow density distributions by year from 2012-2019. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No UWTV survey in 2015.

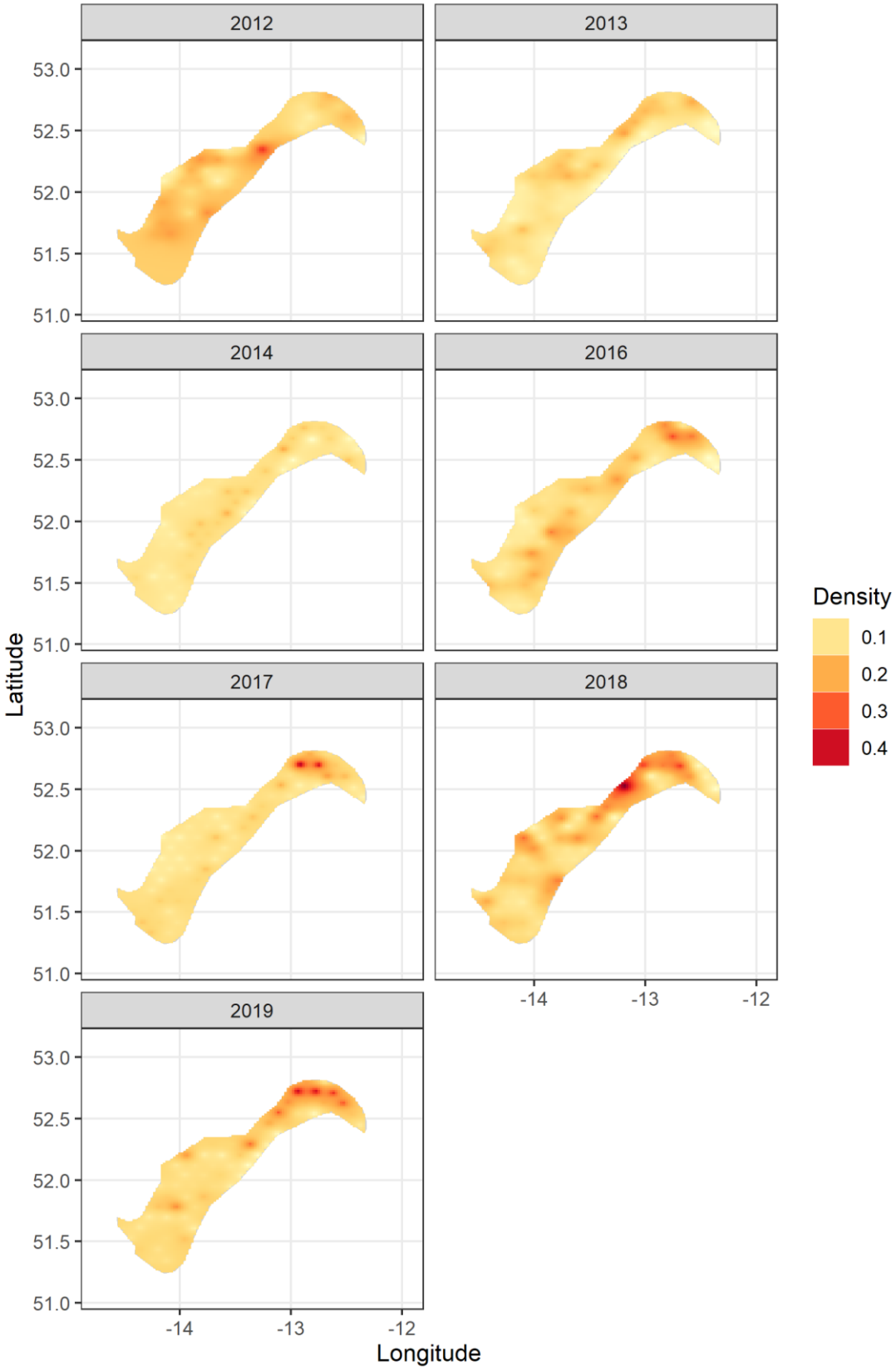

Figure 6: FU16 UWTV 2019. Heat map of *Nephrops* burrow density observations.

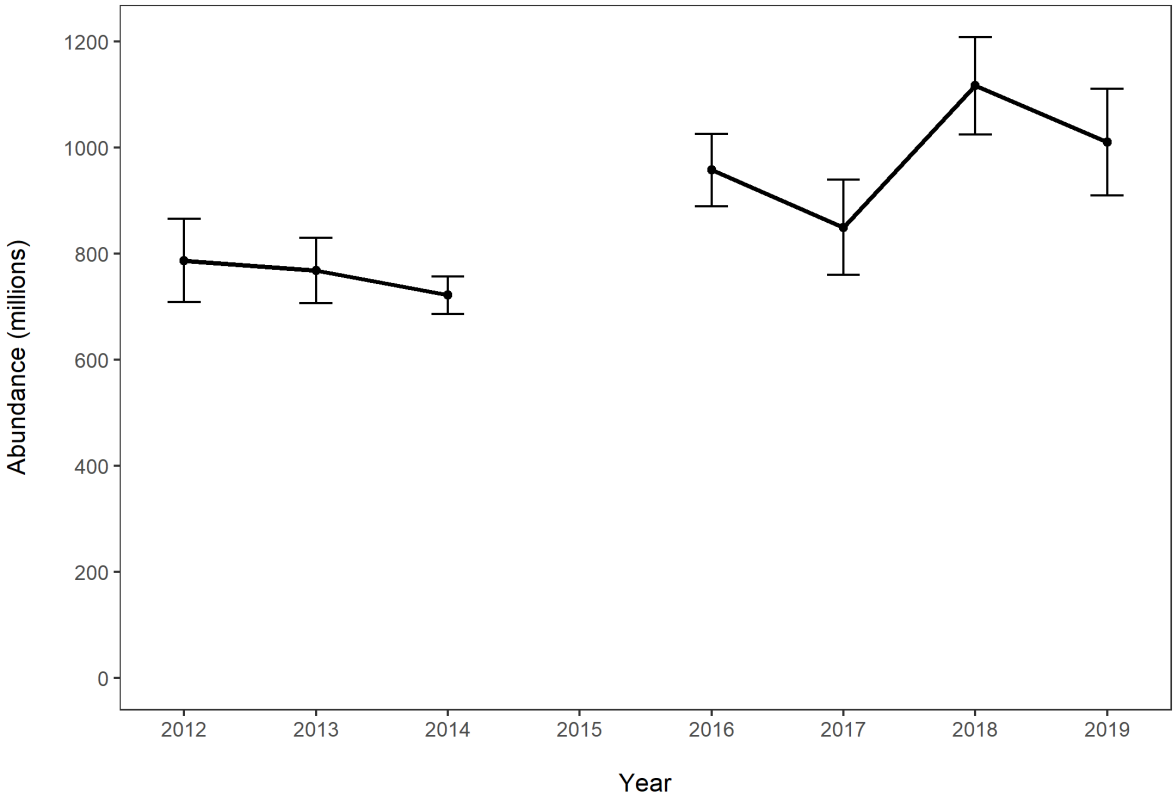

Figure 7: FU16 UWTV 2019. Time series of total abundance estimates for FU16 and 95% confidence intervals. No UWTV survey in 2015.

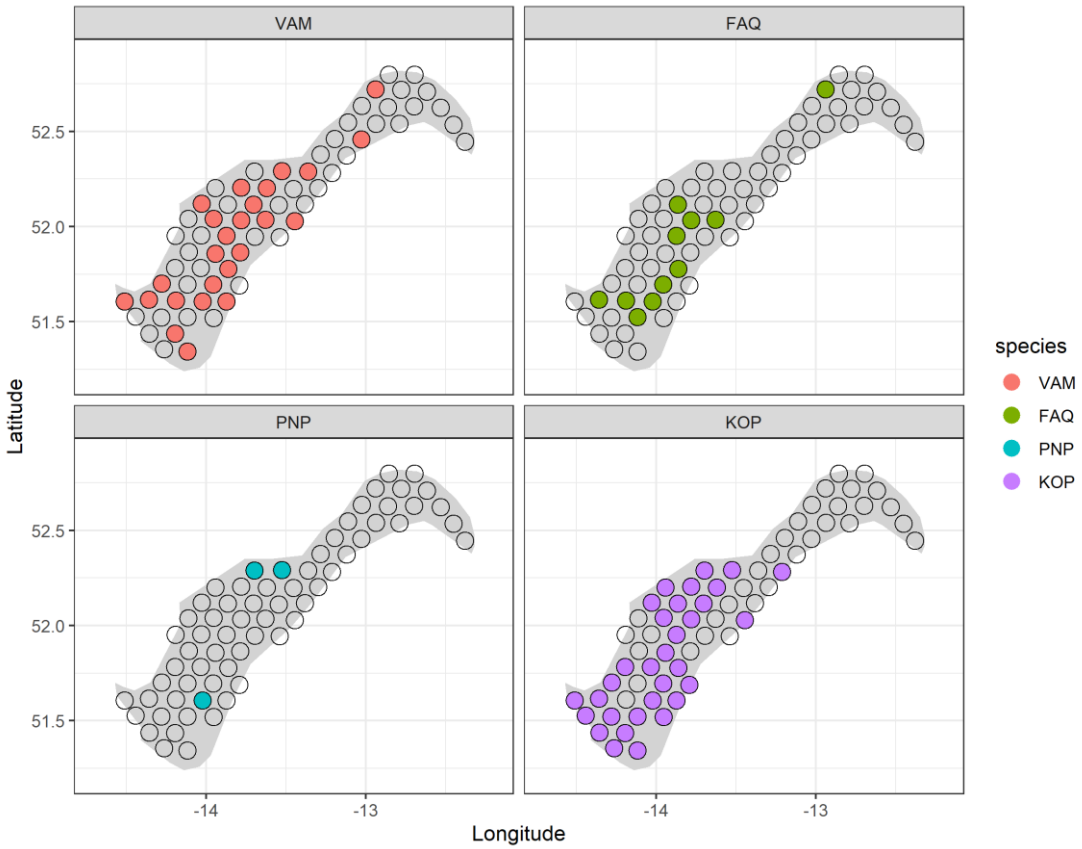

Figure 8: FU16 UWTV 2019. Stations where sea-pens *Virgularia mirabilis* (VAM), *Funiculina quadrangularis* (FAQ), P*ennatula phosphorea* (PNP) and *Kophobelemnon stelliferum* (KOP) were identified from video footage. Coloured circles denote presence in the TV station and empty circles denote TV stations with no sea-pen observations.

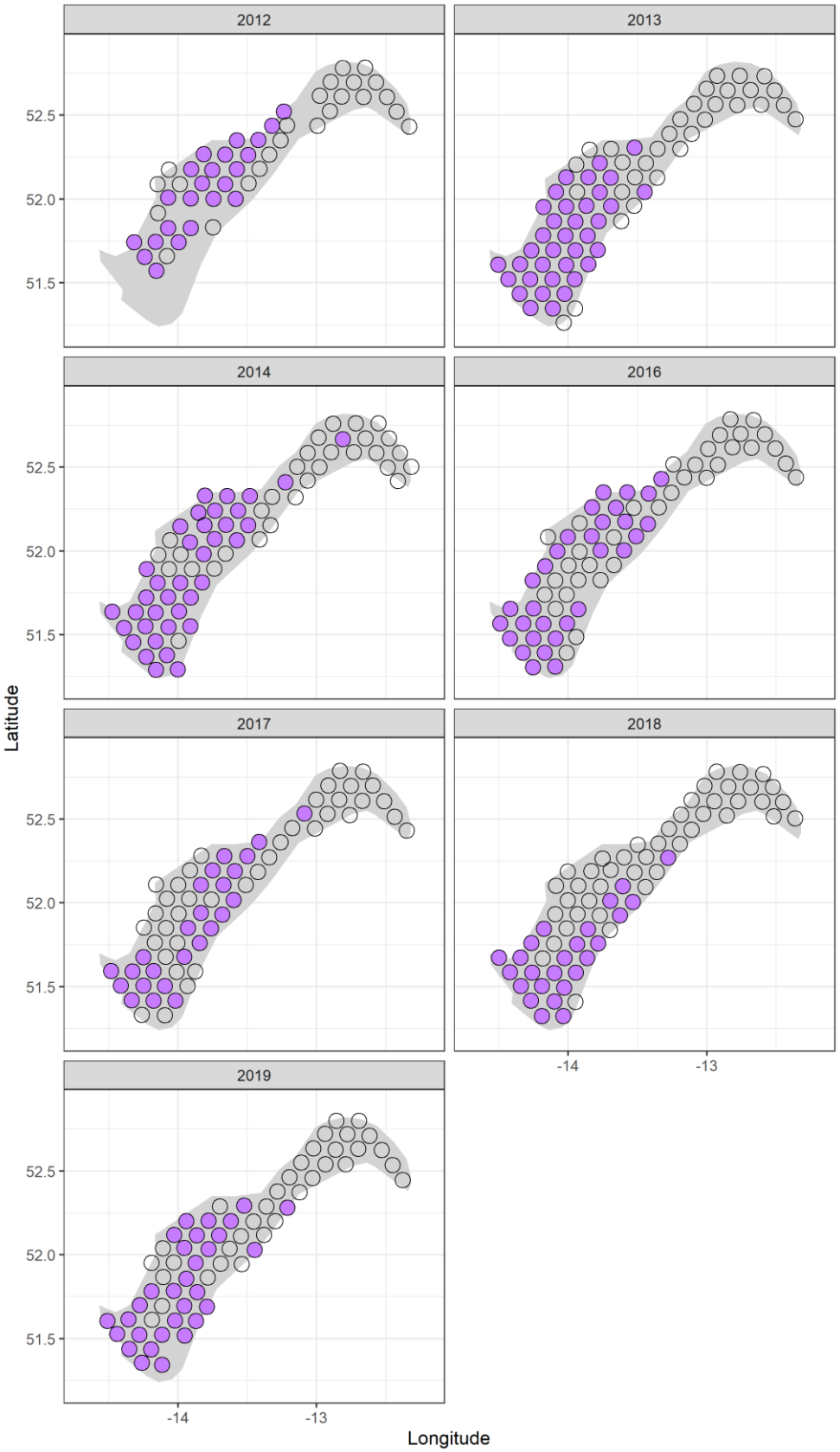

Figure 9: FU16 UWTV 2019. The presence/absence distribution of the deep water sea-pen species *Kophobelemnon stelliferum* (KOP) observed on the video footage from 2012 to 2019 (no survey in 2015). Coloured circles denote presence in the TV station and empty circles denote absence.

Table 1: FU16 UWTV 2019. 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
2019	65	0.012	0.440	0.139	0.011	0.008	1010	7131	0.051

Table 2: FU16 UWTV 2019. Inputs to catch scenarios table.

Year	UWTV abundance estimate	95% Confidence Interval	Landings in number	Total discards in number*	Removals in number	Harvest rate (by number)***	Landings	Total discards*	Discard proportion (by number)	Dead discard proportion (by number)	Mean weight in landings	Mean weight in discards
	Millions					%	tonnes		%		grammes	
2012	787	79	25	0	25	3.2	1258	0	0	0	50.4	NA
2013	768	61	20	0	20	2.6	1141	0	0	0	57.5	NA
2014	722	35	17	0	17	2.4	1189	0	0	0	68.5	NA
2015	NA	NA	27	0	27	3.3**	1394	0	0	0	50.9	NA
2016	958	68	53	NA	53	5.6	2154	NA	NA	NA	40.3	NA
2017	850	90	85	NA	85	10.0	2632	NA	NA	NA	31.0	NA
2018	1117	92	66	NA	66	5.9	2751	NA	NA	NA	41.6	NA
2019	1010	101									53.7	

*Discarding up to 2015 was considered to be negligible. Discard estimates are not available since 2016 and are therefore not included in the assessment.

** The harvest rate is estimated based on a linear interpolation of abundance for 2015 as no survey was carried out in this year.

*** Values since 2016 onwards may be underestimates due to insufficient discard data.

NA = not available.

Table 3: FU16 UWTV 2019. The basis for the catch advice and scenarios.

Variable	Value	Notes
Stock abundance (2020)	1010 million	UWTV survey 2019 (number of individuals).
Mean weight in wanted catch	42.1 g	Average 2017–2019.
Mean weight in unwanted catch	-	Unknown.
Unwanted catch	-	Discarding is assumed negligible.
Discards survival	-	Not applicable.
Dead unwanted catch	-	Assumed to be zero.

Table 4: FU16 UWTV 2019. Annual catch advice and scenarios.

Basis	Total catch	Wanted catch	Unwanted catch	Harvest rate*%	% advice change **
	WC+UC	WC	UC	For WC+UC	
EU MAP ^ : F_{MSY}	2637	2637	0	6.2	-0.3
F = MAP $F_{MSY\ lower}$	2127	2127	0	5.0	-19.6
F = MAP $F_{MSY\ upper}$ ***	2637	2637	0	6.2	-0.3
Other options					
MSY approach	2637	2637	0	6.2	-0.3
F_{2018}	2522	2522	0	5.9	-4.7

^ EU multiannual plan (MAP) for Western Waters (EU, 2019)

* By number

** Advice value for 2020 relative to the advice value for 2019 (2645 tonnes)

*** FMSY upper =FMSY for this stock