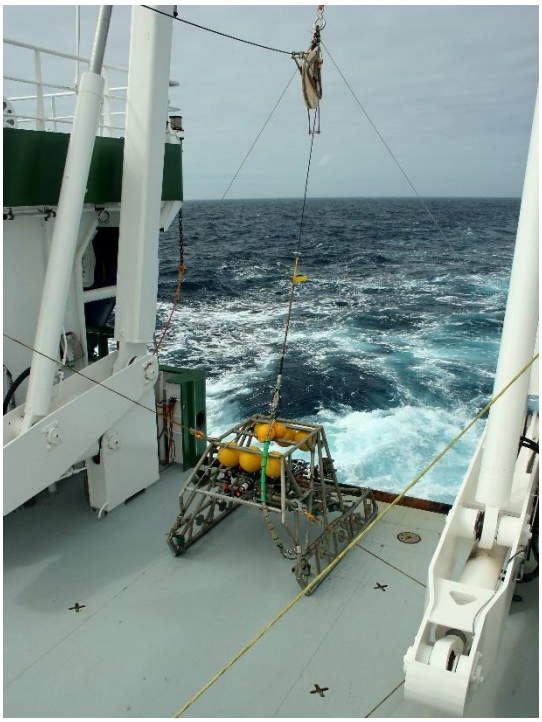
Porcupine Bank *Nephrops* Grounds (FU16)
2022 UWTV Survey Report and catch scenarios for 2023

Mikel Aristegui[1], Jennifer Doyle[1], Marcin Blaszkowski[1], Jessica Harvey[2], Séan O'Connor[1], María Pérez Tadeo[3], Tom Tangye[4], Ennis De Vos[5], Jonathan White[1]

[1] Fisheries Ecosystems Advisory Services, Marine Institute, Rinville, Oranmore, Galway, Ireland.
[2] Centre for Environment Fisheries & Aquaculture Science, Pakefield Road, Lowesoft, Suffolk, UK.
[3] Marine and Freshwater Research Centre, Atlantic Technological University, Galway, H91 T8NW, Ireland.
[4] Joint Nature Conservation Committee, Monkstone House, Peterborough, UK.
[5] Strategic Marine Alliance for Research and Training Student Bursary Programme, Atlantic Technological University, Galway, H91 8NW, Ireland.



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Abstract

This report provides the results of the tenth underwater television on the 'Porcupine Bank *Nephrops* grounds' ICES assessment area; Functional Unit 16. The survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. In total 58 UWTV stations were successfully completed out of the 68 stations planned in a randomised 6 nautical mile isometric grid covering the full spatial extent of the stock. The mean burrow density observed in 2022, adjusted for edge effect, was 0.19 burrows/m². The final krigged abundance estimate was 1363 million burrows with a CV of 3% and an estimated stock area of 7,124 km^2. The 2022 abundance estimate was 34% higher than in 2021. Using the 2022 estimate of abundance and updated stock data imply that catches in 2023 should be between 3054 and 3787 tonnes, according to the EU MAP and ICES MSY approach (assuming that all catch is landed). Three species of sea-pen (*Virgularia mirabilis*, *Funiculina quadrangulari*s and the deepwater sea-pen *Kophobelemnon stelliferum)* were observed during the survey. Trawl marks were also observed on 52% 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 2021 worth around €54 million at first sale. The *Nephrops* fishery on the Porcupine Bank takes place on a large area approximately 7130 km² of complex muddy habitat between depths of 330 – 580m. 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 4000 tonnes, declining since then with some fluctuations (ICES, 2022). The total estimated Irish landings in 2021 were 1611 tonnes.

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 Irish fishing has closed for one month from 1st 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 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 by 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 tenth UWTV survey of the Porcupine Bank *Nephrops* grounds (FU16). The 2022 survey was multi-disciplinary in nature. The specific objectives are listed below:

1. To obtain 2022 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 macrobenthos and fish species and trawl marks on the sea bed.
3. To collect relative abundance and distribution of marine mammals in the area by a Marine Mammal Observer (MMO).

This report details the final UWTV results of the 2022 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 2022 abundance data are used to generate catch options for 2023 in line with the recommendations and procedures outlined at the 2013

ICES benchmark (ICES, 2013) and in the stock annex (ICES, 2013) 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 (vessel monitoring system) data of fishing activity between 2006-2011 targeting *Nephrops* (Lordan *et al.* 2012). The grid spacing was determined based on a time constraint of getting the survey completed within a time window of around 5-6 days. This resulted in 68 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 346 to 580m in depth with an average depth of 460m (Figure 1). Survey timing has generally been 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 2022, due to weather conditions in June, the FU16 survey was postponed and carried out between the 14th and the 23rd of August on the RV. *Tom Crean*.

In 2022 all the stations were surveyed using the High Definition (HD) camera system. These stations recorded by HD still image data was specified at: 12 frames per second with a camera angle of 75°. The digital images were stored on a server and were reviewed during the survey through an in-house developed Image Annotation R Shiny app (Aristegui, 2020). This app allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner.

In 2022 66 stations were planned, but only 58 were successfully completed. 1 station was abandoned due to fishing vessels on the ground, and the other 7 stations were dropped due to weather and time constraints.

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 follow internationally agreed standards as recommended in the Manual for the *Nephrops* Underwater TV Surveys (TIMES) (Dobby *et al*., 2021). These protocols are employed on other UWTV surveys in Irish waters and 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 were collected with a field of view (FOV) of 1.00 metre. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 3 seconds. The navigational data were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009). The USBL Sonardyne navigational data were used to calculate distance over ground for 62% all of stations. However, due to technical problems, corrected ship navigation data were used for the other 22 stations.

In line with recommendations of the Workshop on *Nephrops* Burrow Counting (WKNEPS), all scientists were trained/re-familiarised using HD image data for training material and a reference set (ICES, 2018). All counts were conducted by six trained scientists independent of each other after the survey. The numbers of *Nephrops* burrow systems were counted, where

multiple burrows in close proximity which appeared to be part of a single system were counted as one. *Nephrops* activity in and out of burrows were counted and recorded for each station.

Following the recommendation of ICES Study Group on *Nephrops* Surveys (SGNEPS) the time for verified recounts was 7 minutes (ICES, 2009) 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. Counting more minutes resulted in a more stable mean density estimates for each station.

Presence / absence for the occurrence of trawl marks, fish and other species were also recorded at each station. Presence / absence of sea-pen species were 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 time 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 2022 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 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 79 to 81 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 2022 the field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.00m 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 to 2014 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 and the krigged estimation variance or coefficient of variance (CV) was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997).

Since 2016, the geostatistical analysis has been 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, and a model variogram (*h*) 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 CTD was logged for the duration of each tow using a sled mounted and calibrated RBR*brevio* (rated to 750m depth). This data will be processed at a later stage.

For the first time in an UWTV survey carried out by the Marine Institute, a marine mammal survey was conducted at the same time. This survey was carried out by a dedicated MMO on board who used a standard single platform line-transect methodology to collect data of relative abundance and distribution of marine mammals in the Porcupine Bank. This work was funded through the Marine Biodiversity Scheme, carried out under Ireland's Operational Programme, co-funded by the European Maritime and Fisheries Fund (EMFF) and by the Irish Government. Data have been processed by the MMO and fully documented in a separate report (Pérez Tadeo, 2022) available through the Marine Institute Biodiversity portal.

Results

In 2022, 58 stations were completed successfully on the Porcupine Bank (Figure 1). 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 2022, adjusted[1] for edge effect, was 0.19 burrows/m².

The final modelled density surfaces from 2012 to 2014 and 2016 to 2022 are shown as a heat map in Figure 6. The 2022 burrow surface shows an increase in burrow densities on the usual high-density area to the north of the ground, and also a hot spot on the south-eastern boarder. The abundance estimate derived from the krigged burrow surfaces (and adjusted for edge effect) increased by 34% from 1018 million burrows in 2021 to 1363 million in 2022 (Figure 7 and Table 1) with an estimated area of the ground or domain area of 7,124 km². The estimation CV on the abundance was around 3.4% in 2022.

The potential impact of the missing eight stations in the 2022 survey was analysed in detail, by comparing the densities estimations of the kriging model to densities in adjoining areas from the current survey year and also to densities in the same gap-area from previous survey years.

Trawl marks were observed at 30 out of the 58 surveyed stations (52%). 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 and are usually observed in the UWTV surveys: *Virgularia mirabilis, Pennatula phosphorea* and *Funiculina quadrangularis* (Hughes, 1998). However, *P. phosphorea* was not observed on the 2022

[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).

footage. 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. 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 catch and landings options calculated using the 2022 survey abundance estimate and updated stock data, imply that catches in 2023 should be between 3054 and 3787 tonnes, according to ICES MSY approach (assuming that all catch is landed) (Table 4).

The MMO recorded a total of 36 common dolphins (six sightings), 30 bottlenose dolphins (one sighting), one harbour porpoise, one unidentified dolphin and one unidentified cetacean (Pérez Tadeo, 2022).

Discussion

This was the tenth 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 (353m to 579m) 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 (of 13, 12 and 10 days). Priority was given to the Porcupine Bank which was successfully completed on the third leg in 2022, after moving the first two legs 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. Not completing 8 of the 66 planned stations was considered to have had minimal impact on the abundance estimate and quality of the survey, based on burrow densities in adjoining areas and comparing coefficients of variation from the current and previous survey years.

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 2023 have been calculated using updated landings mean weight data from WGCSE (ICES, 2022). These data are usually estimated using the graded landings information for the fishing industry and sampling data carried out at sea by scientific observer. However, in 2020 and 2021, due to low sampling levels caused by Covid-19 restrictions, sampling was adapted and mean weights estimated from catch samples. An average over the last three years (2019-2021) is used to account for the mean weight in the landings estimated in the recent past. The resulting catch advice for 2023 fishing at the F_{MSY} point is an increase of 35%), due to the higher 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, and also the deepwater sea-pen *Kophobelemnon stelliferum*. Data of the four sea-pen species from FU16 are submitted as part of an annual ICES data call to Working Group on Deep-water Ecology (WGDEC). This dataset provides information regarding the impact of fisheries on components of the ecosystem. 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 52% of stations showed some trawl marks is consistent with previous years.

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Photography credits

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Disclaimer

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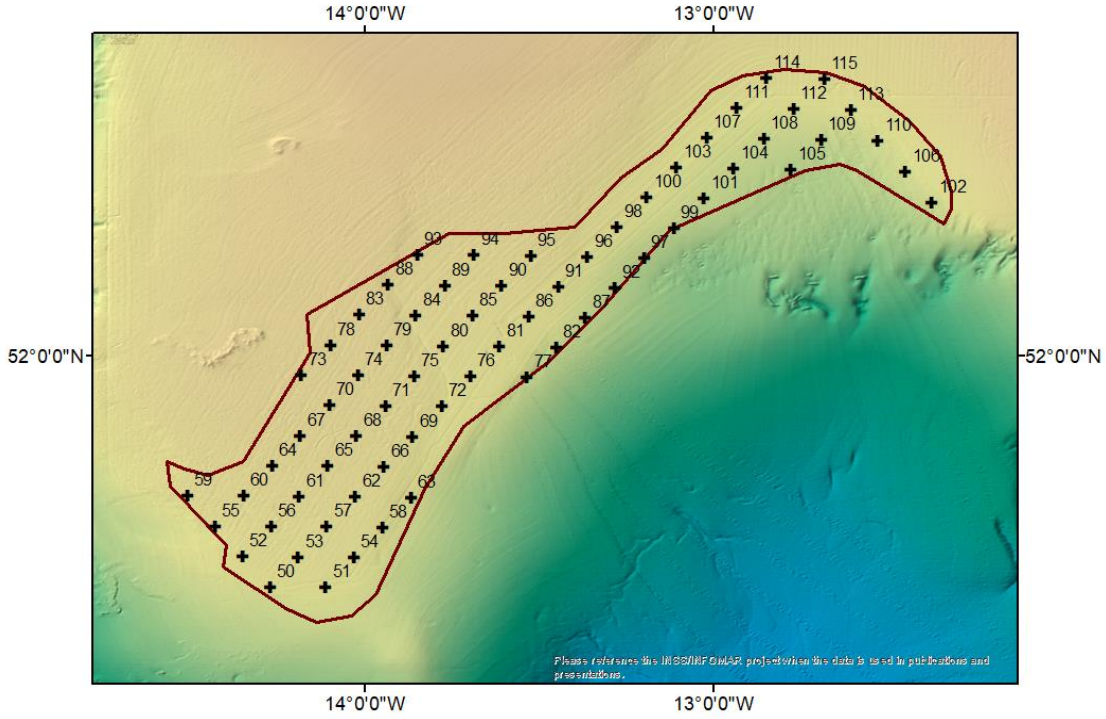

Figure 1: FU16 UWTV 2022. UWTV map of station positions and bathymetry. The polygon line indicates the ground boundary currently used.
Source: INFOMAR is the Department of Communications, Climate Action and Environment (DCCAE) funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and Marine Institute

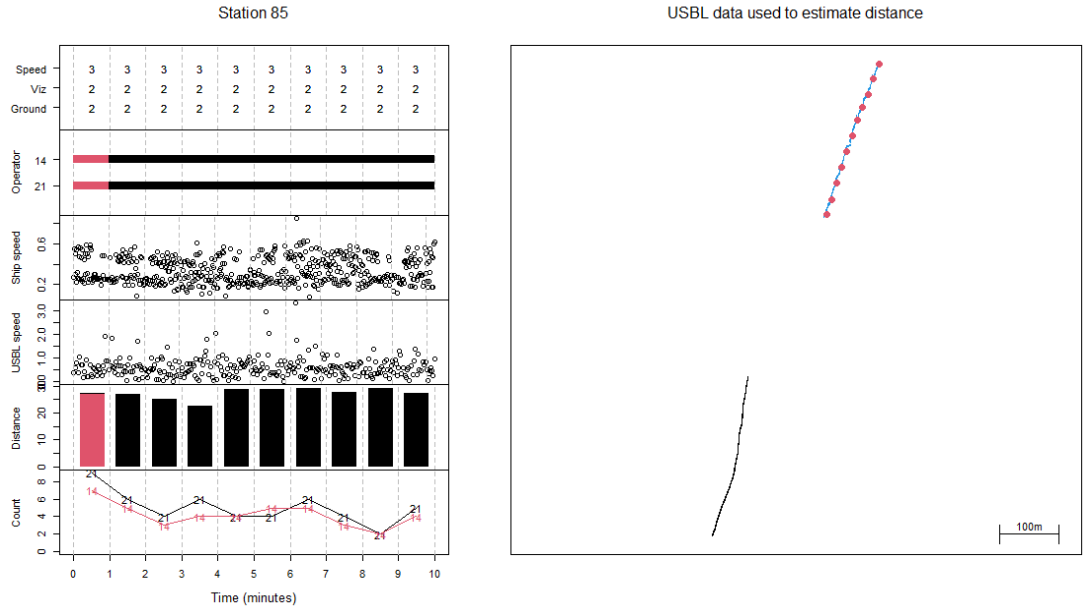

Figure 2: FU16 UWTV 2022. UWTV example quality control plot for the navigational and recount data.

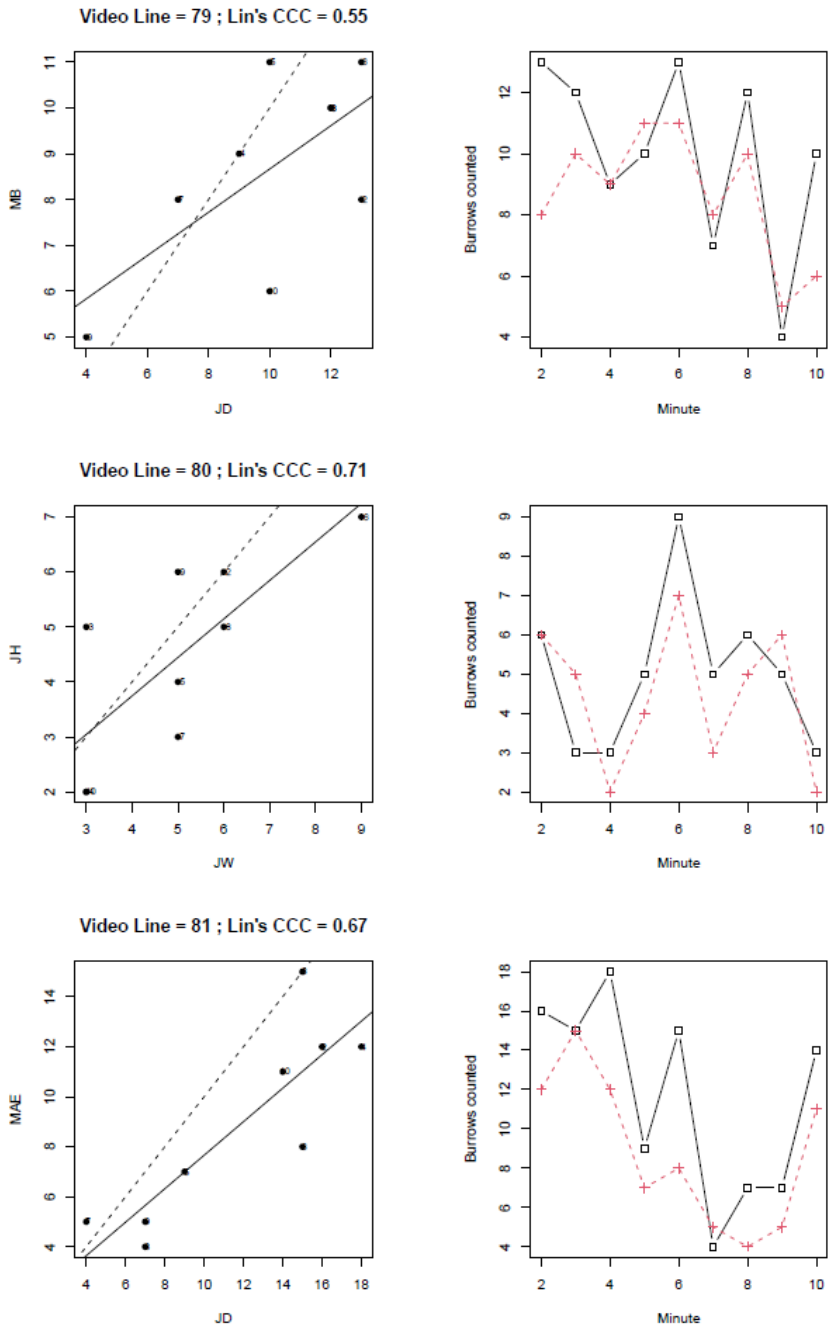

Figure 3: FU16 UWTV 2022. Lin's CCC quality control plot of count data for stations 79 to 81 from the 2022 survey.

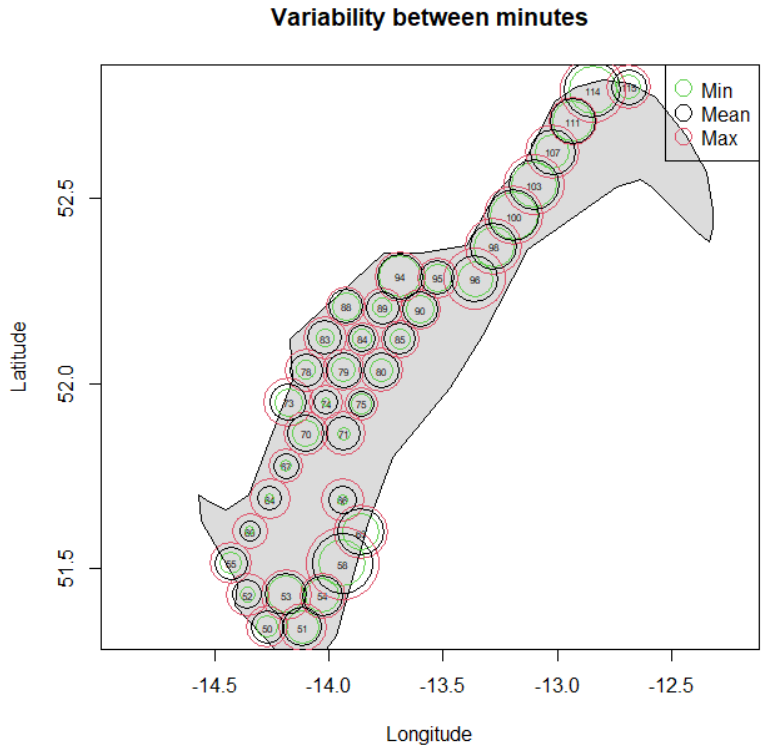

Figure 4: FU16 UWTV 2022. UWTV quality control plot showing variability between minutes for each UWTV station

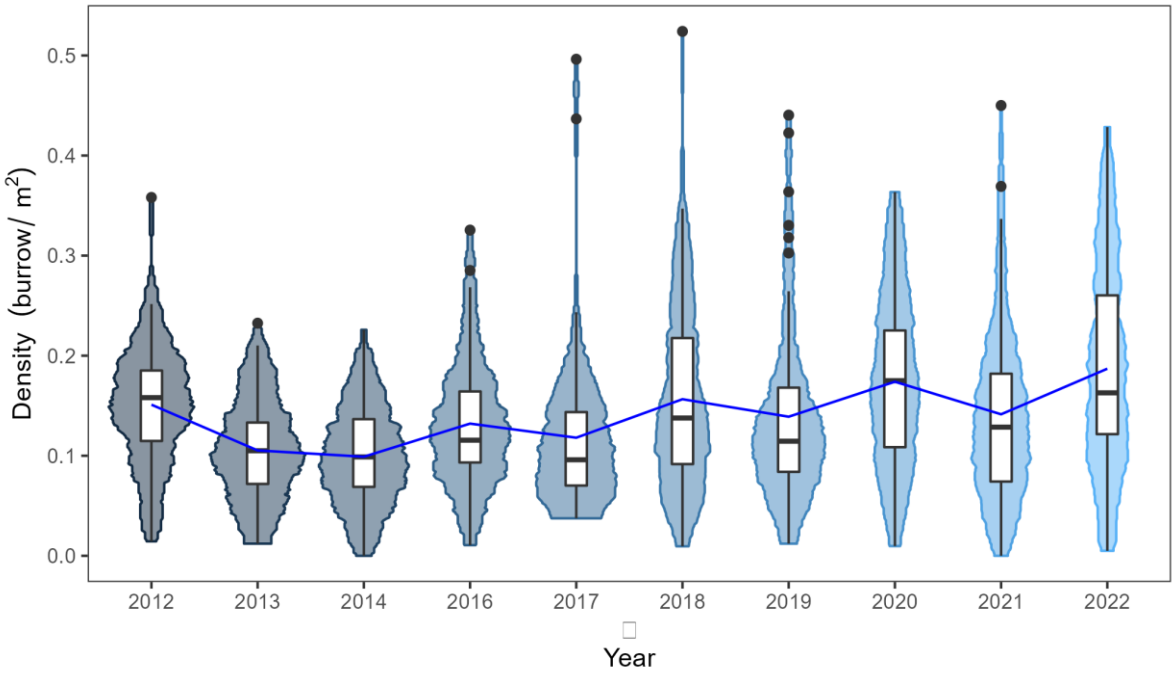

Figure 5: FU16 UWTV 2022. Violin and box plot of adjusted burrow density distributions by year from 2012-2022. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No UWTV survey in 2015.

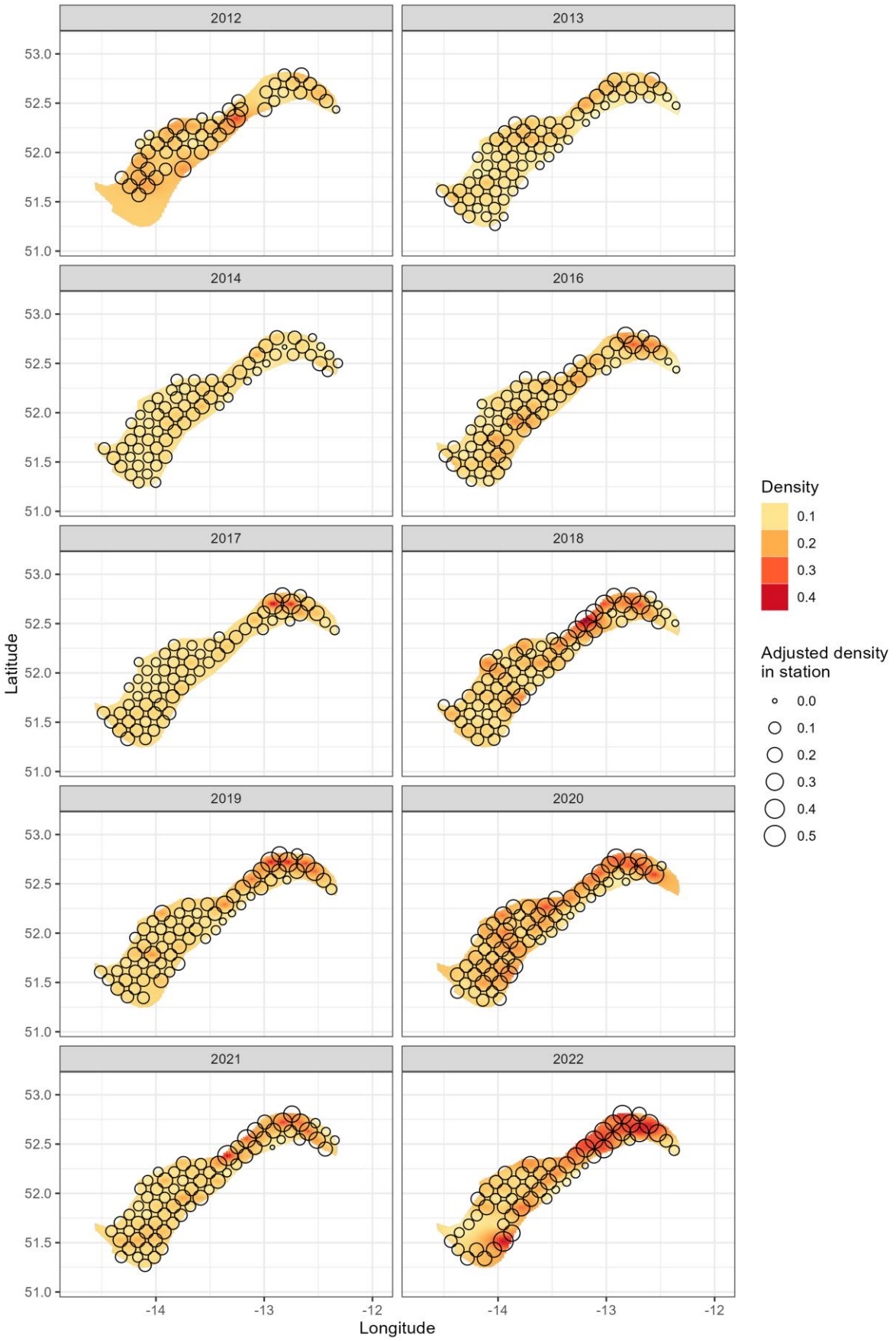

Figure 6: FU16 UWTV 2022. Heat map of *Nephrops* burrow density observations from 2012 to 2022.

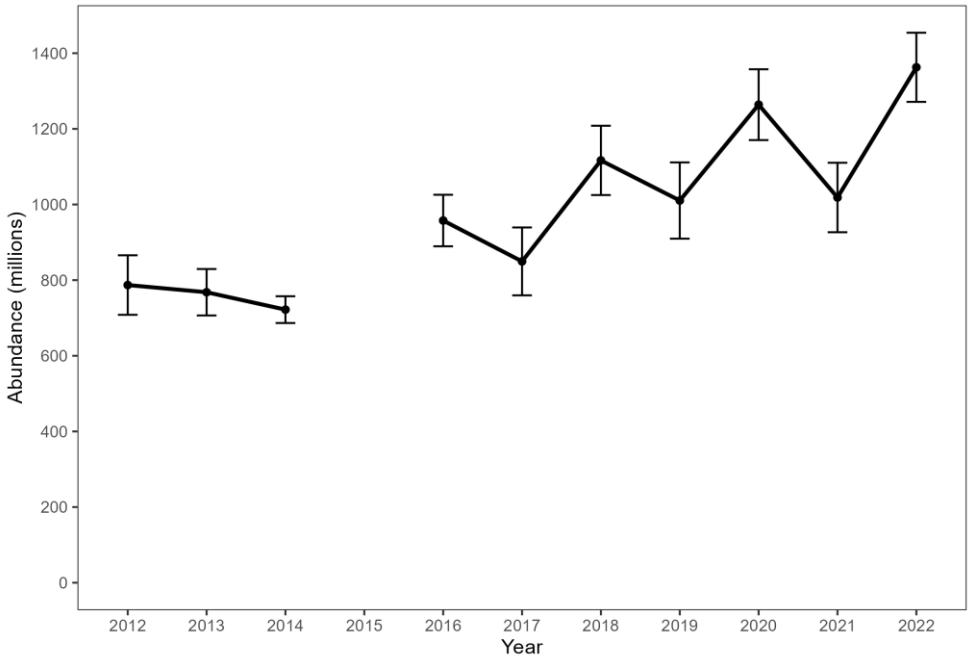

Figure 7: FU16 UWTV 2022. Time series of total abundance estimates for FU16 and 95% confidence intervals. No UWTV survey in 2015.

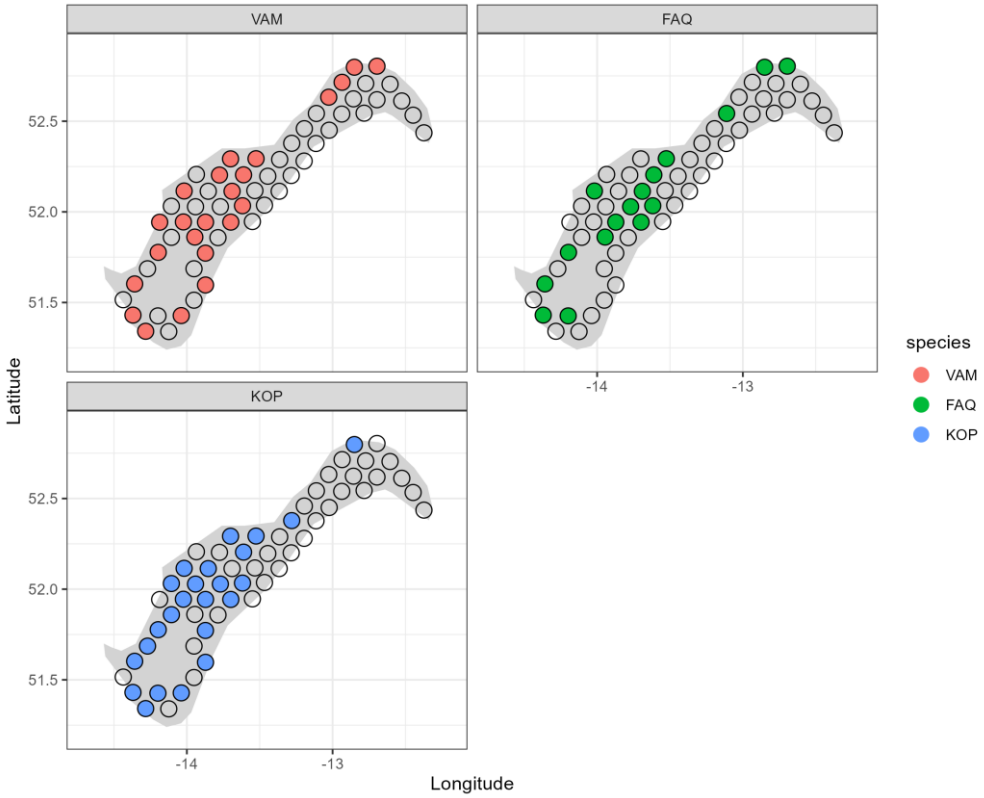

Figure 8: FU16 UWTV 2022. Stations where sea-pens *Virgularia mirabilis* (VAM), *Funiculina quadrangularis* (FAQ) and *Kophobelemnon stelliferum* (KOP) were identified from video footage. Coloured circles denote presence in the TV station and empty circles denote TV stations with no sea-pen observations.

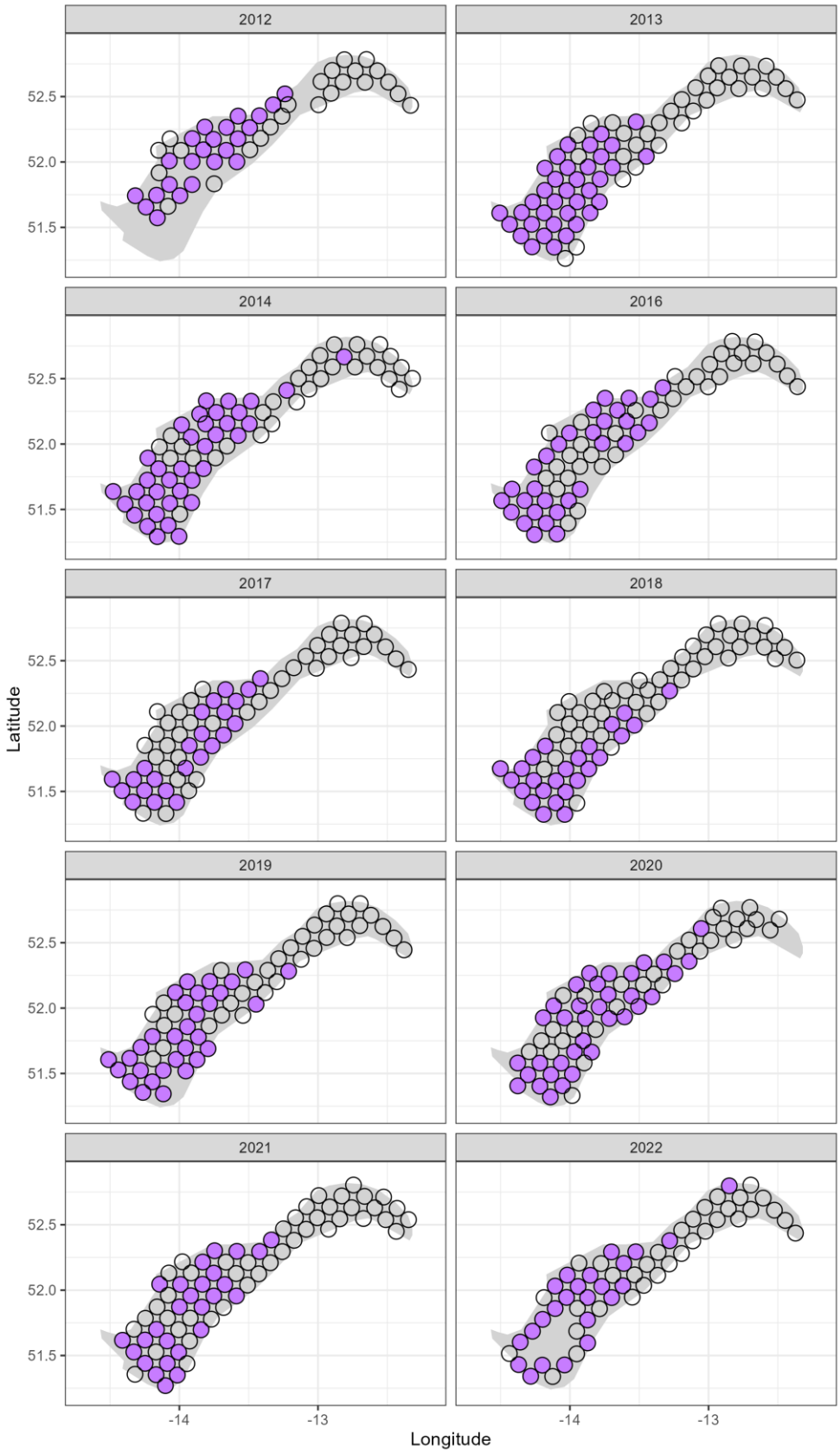

Figure 9: FU16 UWTV 2022. The presence/absence distribution of the deep water sea-pen species *Kophobelemnon stelliferum* (KOP) observed on the video footage from 2012 to 2022 (no survey in 2015). Coloured circles denote presence in the TV station and empty circles denote absence.

Table 1: FU16 UWTV 2022. Summary of univariate statistics and geostatistics for the burrow density estimates (bias corrected) on the Porcupine Bank UWTV survey in 2012-2022. No TV survey in 2015.

	Univariate Statistics					**Geostatistics**		
Year	Number of Observations	Min	Max	Mean	Standard Deviation	Adjusted abundance estimate (millions)	Domain area (km^2)	Coef. Of Variation
2012	47	0.014	0.358	0.151	0.063	787	7108	0.049
2013	68	0.012	0.233	0.106	0.051	768	7108	0.044
2014	67	0	0.226	0.099	0.049	722	7108	0.025
2015	0							
2016	65	0.011	0.325	0.132	0.0055	958	7108	0.036
2017	63	0.037	0.496	0.118	0.0082	850	7134	0.054
2018	69	0.095	0.524	0.156	0.011	1117	7130	0.042
2019	65	0.012	0.440	0.139	0.011	1010	7131	0.051
2020	65	0.0097	0.364	0.174	0.0097	1264	7133	0.038
2021	71	0	0.450	0.141	0.0096	1018	7129	0.046
2022	58	0.005	0.428	0.190	0.0131	1363	7124	0.034

Table 2: FU16 UWTV 2022. Inputs to catch scenarios table.

Year	UWTV abundance estimate	High 95% confidence interval	Low 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	866	708	25	0	25	3.2	1258	0	0	0	50.36	NA
2013	768	829	707	20	0	20	2.6	1141	0	0	0	57.54	NA
2014	722	757	687	17	0	17	2.4	1189	0	0	0	68.54	NA
2015	NA	NA	NA	27	0	27	3.3***	1394	0	0	0	50.86	NA
2016	958	1026	889	53	NA	53	5.6	2154	NA	NA	NA	40.29	NA
2017	850	939	760	85	NA	85	10.0	2632	NA	NA	NA	31.01	NA
2018	1117	1208	1025	66	NA	66	5.9	2751	NA	NA	NA	41.55	NA
2019	1010	1111	910	42	NA	42	4.1	2229	NA	NA	NA	53.38	NA
2020	1263	1358	1170	50	NA	50	3.9	1899	NA	NA	NA	38.26	NA
2021	1018	1110	927	58	NA	58	5.7	2476	NA	NA	NA	42.82	NA
2022	1363	1454	1271										

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

** Values since 2016 onwards may be underestimated owing to insufficient discard data.

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

NA = not available.

Table 3: FU16 UWTV 2021. The basis for the catch advice and scenarios.

Variable	Value	Notes
Stock abundance (2023)	1363	UWTV survey 2022; individuals in millions
Mean weight in projected landings	44.82	Average 2019–2021; in grammes
Mean weight in projected discards	-	Unknown
Projected discard rate	-	Unknown
Discards survival rate	-	Not applicable

Table 4: FU16 UWTV 2021. Annual catch advice and scenarios.

Basis	Total catch	Projected landings	Projected discards	Harvest rate * %	% advice change **
	PL + PD	PL	PD	For PL + PD	
ICES advice basis					
EU MAP^: F_{MSY}	3787	3787	0	6.2	35
EU MAP^: $F_{MSY\ lower}$	3054	3054	0	5.0	35
EU MAP^: $F_{MSY\ upper}$***	3787	3787	0	6.2	35
Other scenarios					
MSY approach	3787	3787	0	6.2	35
F_{2021}	3467	3467	0	5.7	24

* By number.

** Advice values for 2023 relative to the corresponding 2022 values (MAP advice of 2804, 2261, and 2804 tonnes, respectively); other option values are relative to 2804 tonnes.

*** $F_{MSY\ upper} = F_{MSY}$ for this stock.

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