

The “Smalls” *Nephrops* Grounds (FU22) 2022 UWTV Survey Report and catch scenarios for 2023

Jennifer Doyle¹, Mikel Aristegui¹, Séan O’Connor¹, Mairéad Sullivan¹, Michael Kinneen¹, Sharon Sugrue¹ and Cian Derbyshire¹.

¹ Fisheries Ecosystems Advisory Services, Marine Institute, Renville, Oranmore, Galway, Ireland.



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Abstract

This report provides the main results and findings of the seventeenth annual underwater television survey on the 'Smalls grounds' ICES assessment area; Functional Unit 22. The survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. A total of 42 UWTV stations were surveyed successfully (high quality image data), carried out over an isometric grid at 4.5nmi or 8.3km intervals. The precision, with a CV of 7%, was well below the upper limit of 20% recommended by SGNEPS (ICES, 2012). The 2022 abundance estimate was 36% higher than in 2021 and at 895 million is below the MSY $B_{trigger}$ reference point (990 million). Using the 2022 estimate of abundance and updated stock data implies catch in 2023 that correspond to the ICES MSY approach of 2548 tonnes, assuming that discard rates and fishery selection patterns do not change from the average of 2019 - 2021. One species of sea pen was recorded as present at the stations surveyed: *Virgularia mirabilis*. Trawl marks were observed at 29% of the stations surveyed.

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

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows (Figure 1). The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2020 worth around €35 m at first sale. The Celtic Sea area (Functional Units 19-22, see Figure 1) supports a large multi-national targeted *Nephrops* fishery, mainly using otter trawls and yielding landings in the region of ~5,000 t annually over the last decade (ICES, 2022). The Smalls ground is particularly important to the Irish demersal fleet accounting for around 13% of the fishing effort by all demersal vessels >15m in length, between 2006 and 2009 (Gerritsen, *et al.*, 2012). The Irish demersal fleet now account for ~95% of the FU 22 *Nephrops* landings (ICES, 2022). Good scientific information on stock status and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of year, light intensity, tidal strength, etc. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009 & 2012). This is the seventeenth in a time series of UWTV surveys in the Celtic Sea FU22 “Smalls” ground carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and also covered UWTV stations in FU 19 and FU 20-21, the results of which are presented elsewhere (Doyle *et.al.*, 2022a&b).

The specific objectives of the 2022 survey are listed below:

1. To complete a survey of 41 randomised fixed isometric grid UWTV stations, with 4.5 nautical mile (nmi) spacing, on the “Smalls” *Nephrops* ground (FU 22).
2. To obtain 2022 quality assured estimates of *Nephrops* burrow distribution and abundance on the “Smalls” *Nephrops* ground (FU 22) and compare them with those collected in previous surveys.
3. 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.

This report details the UWTV results of the 2022 survey and documents other data collected during the survey. Operational survey details are available in the form of a survey narrative available from the scientist in charge (MA). The 2022 abundance estimate is used to generate catch scenarios for 2023 in line with procedures outlined in the stock annex for FU22 (ICES, 2022).

Material and methods

To maintain a coefficient of variance (CV) < 20%, to achieve good spatial coverage over the ground and to generate a burrow surface that reflects the underlying abundance of *Nephrops*, a survey grid of 4.5 nm spacing has been used since 2012. The 2022 randomised isometric grid, which resulted in 41 planned stations (Figure 2), was generated using using the “spsampl” function in the “sp” package (Pebesma & Bivand, 2005) in “R” (R Core Team, 2017). The boundary used to delineate the edge of the ground was based on information from VMS

(Gerritsen & Lordan, 2011), habitat maps, and previous UWTV observations. The same boundary has been used through the time series.

The 2022 Celtic Sea survey took place on RV. *Celtic Voyager* between the 23rd May and the 4th June. The survey normally takes place in either July or August each year.

In 2022 image data were collected by a custom built camera system recording High Definition (HD) 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 at sea through an in-house developed Image annotation R Shiny app (Aristegui, M., 2020). This app allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner. The survey process is now paperless.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and follow internationally agreed standards as recommended in the Manual for the *Nephrops* Underwater TV Surveys (TIMES) (Dobby H., *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 or 'FOV' of 1.00 metres. 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) an example is shown in Figure 3. In 2022 the USBL navigational data were used to calculate distance over ground for 100% of stations.

A new HD reference set was developed in 2020 for training material and reference set (ICES, 2021). In line with recommendations of the Workshop on *Nephrops* Burrow Counting (WKNEPS), all scientists were trained/re-familiarised (ICES, 2018). All counts were conducted by trained scientists independent of each other onboard. The numbers of *Nephrops* burrows systems (multiple burrows in close proximity which appear 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 SGNEPS the time for verified recounts was 7 minutes (ICES, 2009).

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 the one-minute block where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time could be removed from the distance over ground calculations.

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 plots of survey count data for stations

stations 164, 165 and 166 are shown in Figure 4. 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. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.00 metre assuming that the sledge was flat on the seabed (i.e. no sinking). Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud. The impact of this is a minor under estimate of densities at stations where this occurred.

From 2006 to 2014 calculation of spatial co-variance, spatial structuring, geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. From 2015 the geostatistical analysis was carried out using the "RGeostats" package (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 produced with an exponential model, create a 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.

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 in-house and is considered an emerging time series.

Results

In 2022 41 stations were completed successfully on the Smalls. A summary of the results is presented in Table 1. The density and estimated abundance increased by around 33% in 2022. The average density and the abundance were the fifth lowest in the time series. Figure 5 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are very consistent between minutes and counters. 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 between 0.2 and 0.7 in most years. However, in 2022 as in years 2021, 2020, 2018 and 2016, this inter-quartile range was lower, in the region of 0.1 to 0.4. In 2022 the mean adjusted¹ burrow density was 0.31 burrows/m². The adjusted geostatistical abundance estimate is derived using the mean of the krigged grid, where the mean of the observations is reported in Table 1.

The krigged and point density data for 2006 to 2022 are shown in Figure 7. The krigged contours correspond well to the observed data. In general, highest densities show a tendency towards the centre of the ground in all years, with some variability to this of higher values towards the south, west and central area of the ground.

¹ Note the "adjusted" density estimates in this report are adjusted by dividing by 1.3 (Table 2) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

The annual survey statistics from this geo-statistical analysis are given in Table 1 and Figure 8. The 2022 estimate of 895 million burrows is below the geometric mean of the series (geomean [2006-2022]: 1125 million burrows) and is below the $MSY_{B_{trigger}}$ reference point of 990 million. The estimation of variance of the 2022 survey as calculated by RGeostats is low (with a CV or RSE of 7%), which is well below the SGNEPS recommendation for a CV <20% (ICES, 2012).

Figure 9 shows the standardised length frequency distributions of *Nephrops* caught using a beam trawl over the time series. Fishing operations were not carried out during for several years (2010, 2013, 2014, 2015, 2019 and 2022) due to time constraints and also were not possible in 2020 and 2021 owing to minimal staffing levels on the survey due to COVID-19 pandemic. For plotting purposes, the individuals <10mm caught were split evenly between males and females as it is not possible to accurately assign sex to individuals of this size. A strong cohort was apparent in the 2006 catches of around 17mm and can be tracked in catches in subsequent years. There was a shift to larger sizes in 2011 and 2012, with a shift back again to smaller sizes in 2016 to 2018.

Sea-pen presence/absence distribution across the Smalls *Nephrops* grounds is mapped in Figure 10. One species of sea-pen (*Virgularia mirabilis*) was identified across the survey area from image data in 2022. Trawl marks were noted at 29% of the stations surveyed.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number, were used to calculate the harvest rate for 2021 of 10.7%. The mean weight in the landings and discards and the proportions of removals retained are also shown (Table 2).

The basis to 2023 catch scenarios are given in Table 3. The catch and landings scenarios at various different fishing mortalities were calculated in line with the stock annex of the Report of the Working Group on Celtic Seas Ecoregion (ICES, 2022) using the 2022 survey abundance (Table 4). The latest estimate of stock abundance (result from June 2022 survey, 895 million) is below the $MSY_{B_{trigger}}$ (990 million). ICES maximum sustainable yield (MSY) approach states that under such conditions the F_{MSY} harvest rate (12.8% for FU 22 Norway lobster) should be reduced by multiplying it by the ratio of the current abundance to $MSY_{B_{trigger}}$. This corresponds to a harvest rate of $[12.8 \times (895/990)] = 11.6\%$ for the catch advice in 2023. Fishing at the F ranges in 2023 would result in catches of no more than 2548 tonnes assuming that discard rates and fishery selection patterns do not change from the average of 2019–2021.

Discussion

Since 2006 a dedicated annual UWTV survey has taken place which gives abundance estimates for this ground with high precision. The burrow abundance and mean density estimates have increased in 2022 to the fifth lowest level observed in the series. Sudden

declines followed by large increases in abundance have also been observed in other *Nephrops* stocks in the past (e.g. FU19 and FU20-21 in 2017 to 2019).

Nephrops in this area have been covered under the landings obligation since 2016 with several exemptions. Discard rates in weight for this FU have been around 12% in recent years. The provision of catch advice and scenarios for 2023 assumes that discard rates and fishery selection patterns do not change from the average of 2019-2021.

The introduction of the landings obligation to *Nephrops* fisheries in 2016 should result in changes in selectivity. This is not taken into account in any of the catch advice because it is not possible to predict impacts exactly. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This will in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey was to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES, 2008).

Monitoring the occurrence and frequency of sea-pens observed on this ground is important in the context of OSPAR's designations of sea-pen and burrowing megafauna communities as threatened. The sea-pen species *Virgularia mirabilis* which was seen in 2022 have been observed on previous surveys of FU22. Monitoring *Nephrops* stock and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity).

The main objectives of the survey were successfully met for the seventeenth successive year. The UWTV coverage and footage quality was excellent throughout the survey. This was mainly due to good survey planning to coincide with slack tides. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

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Photography credits

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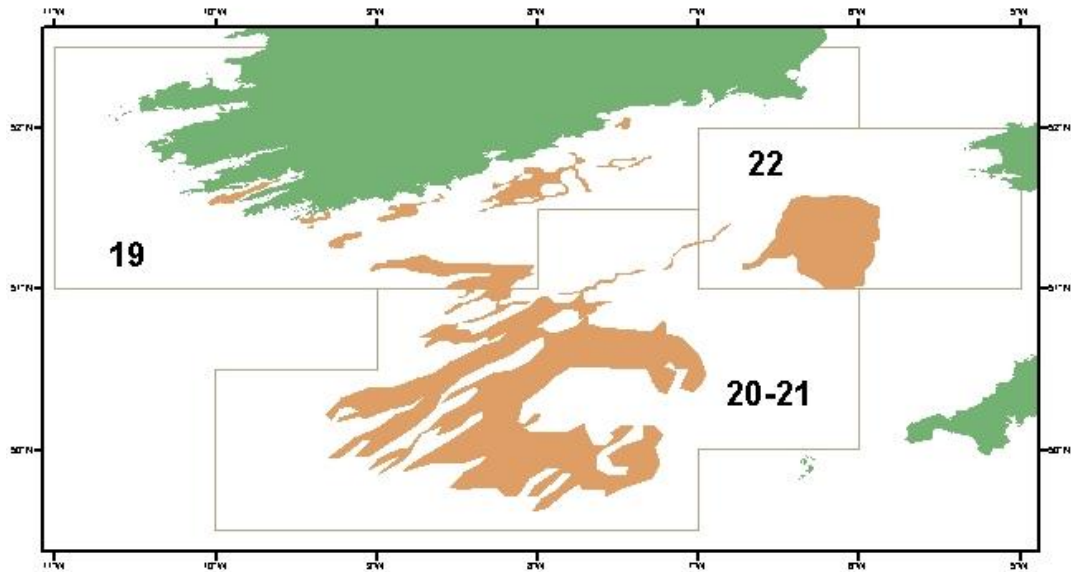


Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) and *Nephrops* grounds (area polygons) in the greater Celtic Sea.

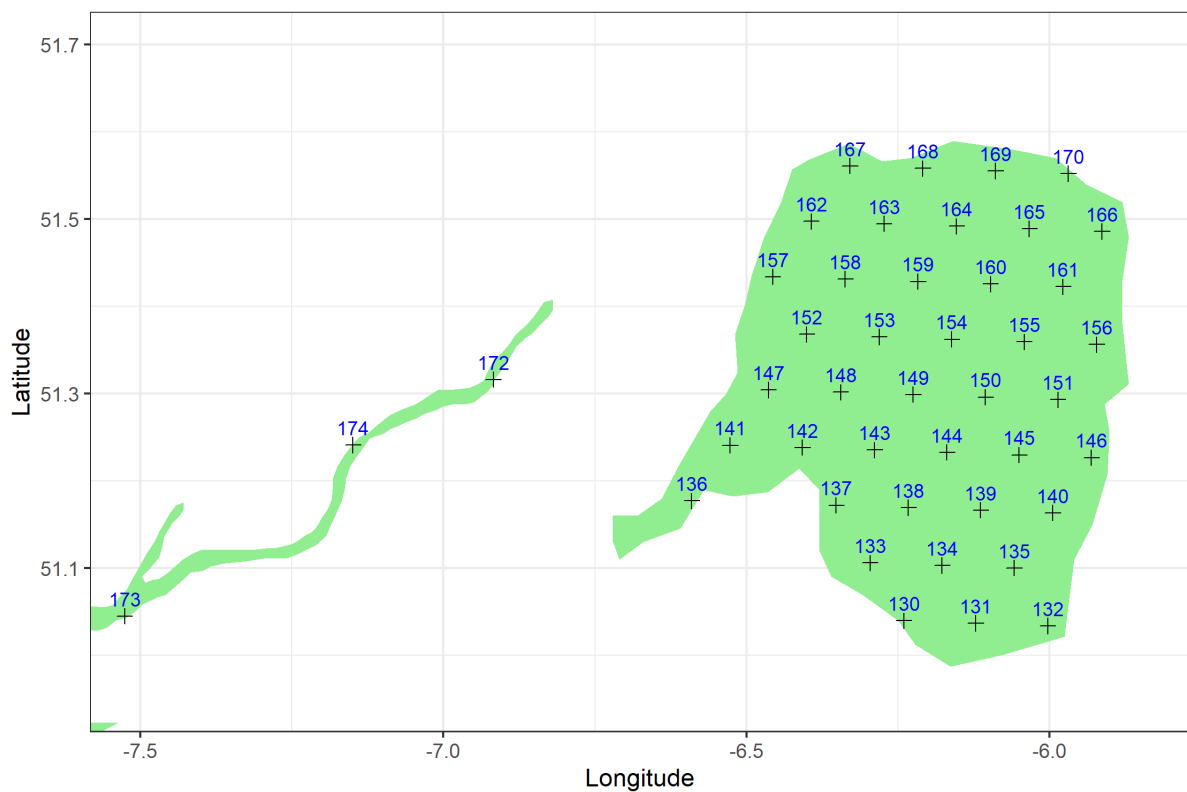


Figure 2: FU22 Smalls grounds: TV stations completed on the 2022 survey.

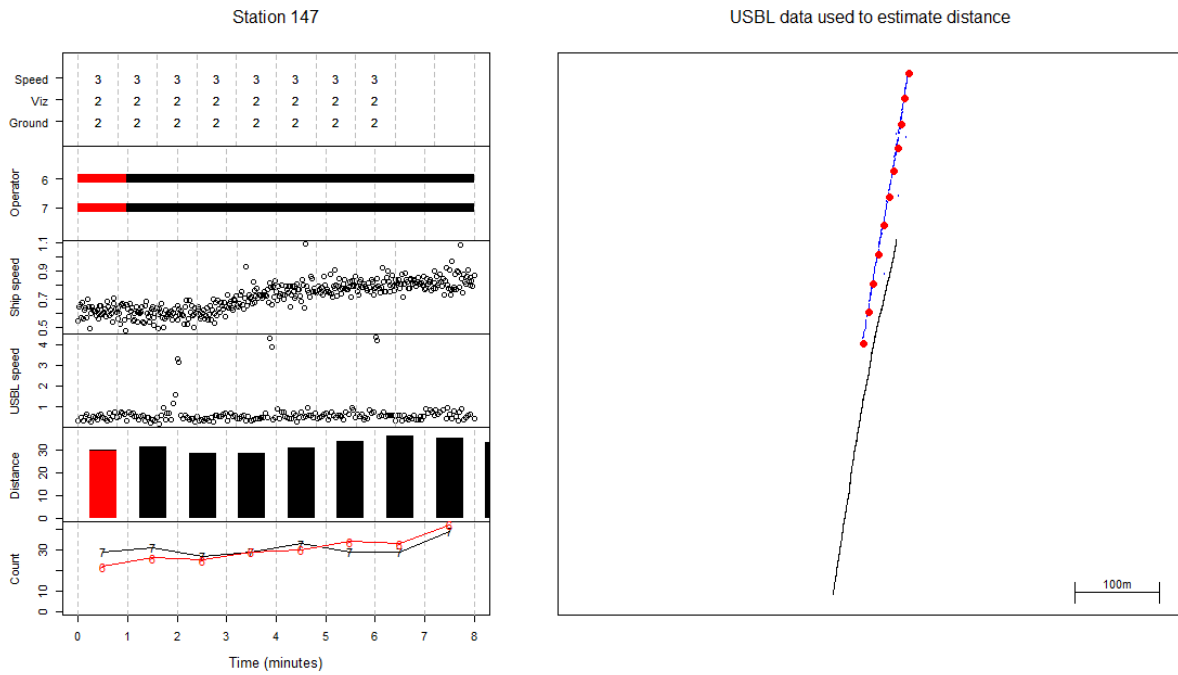


Figure 3: FU22 Smalls grounds: R - tool quality control plot for station 147 of the 2022 survey.

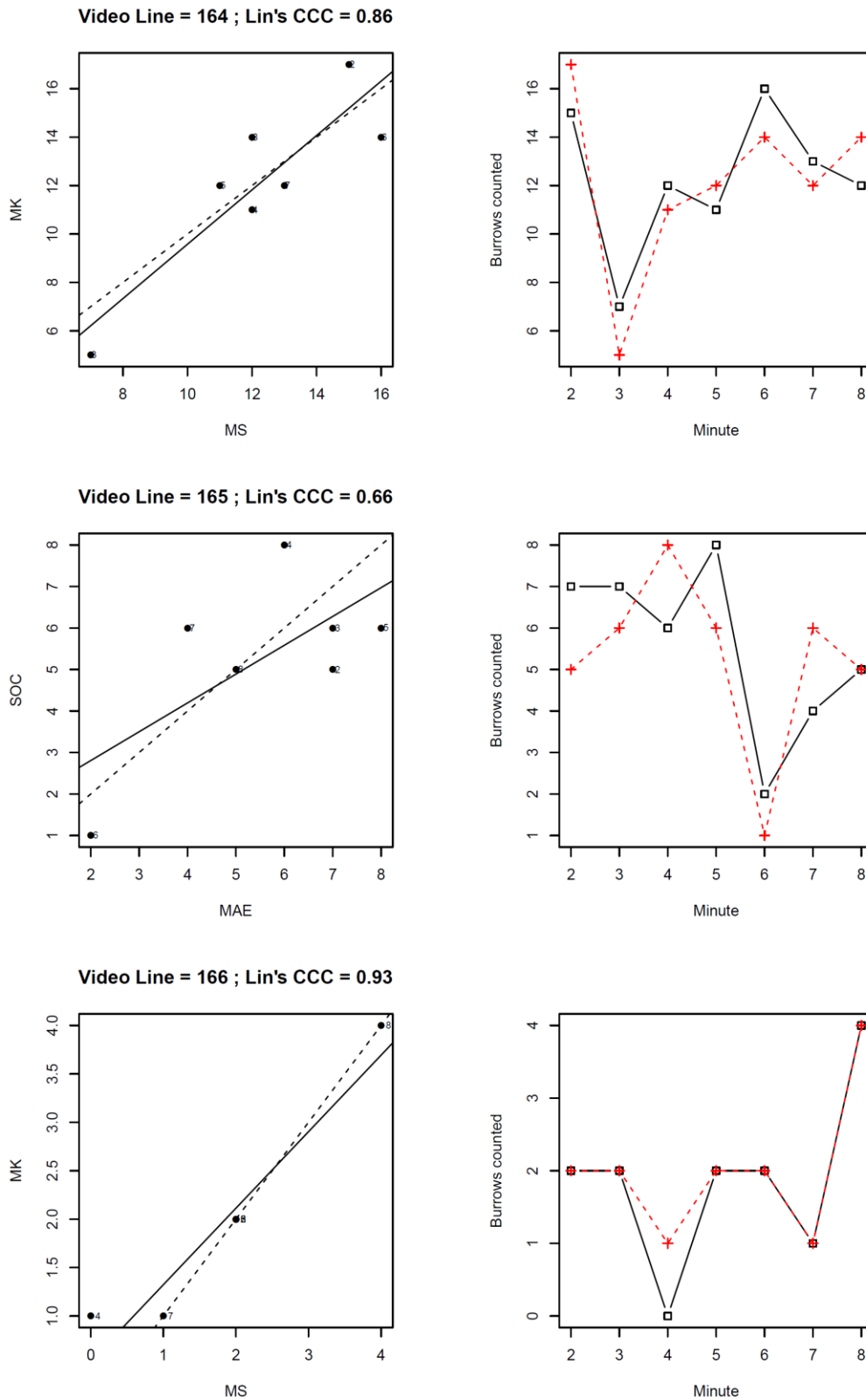


Figure 4 : FU22 Smalls grounds: Lin's CCC quality control plots of count data for stations 164, 165 and 166 of the 2022 survey.

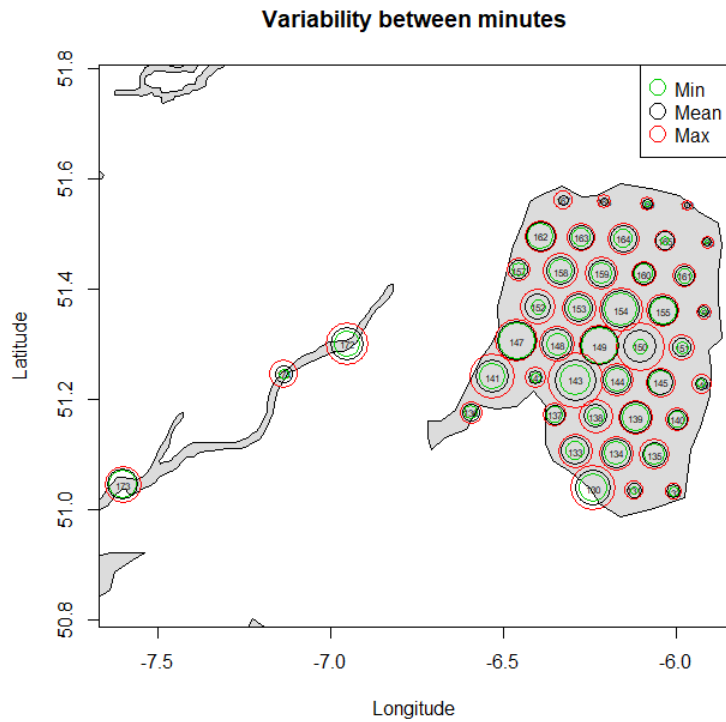


Figure 5: FU22 Smalls grounds: Plots of the variability in density between minutes.

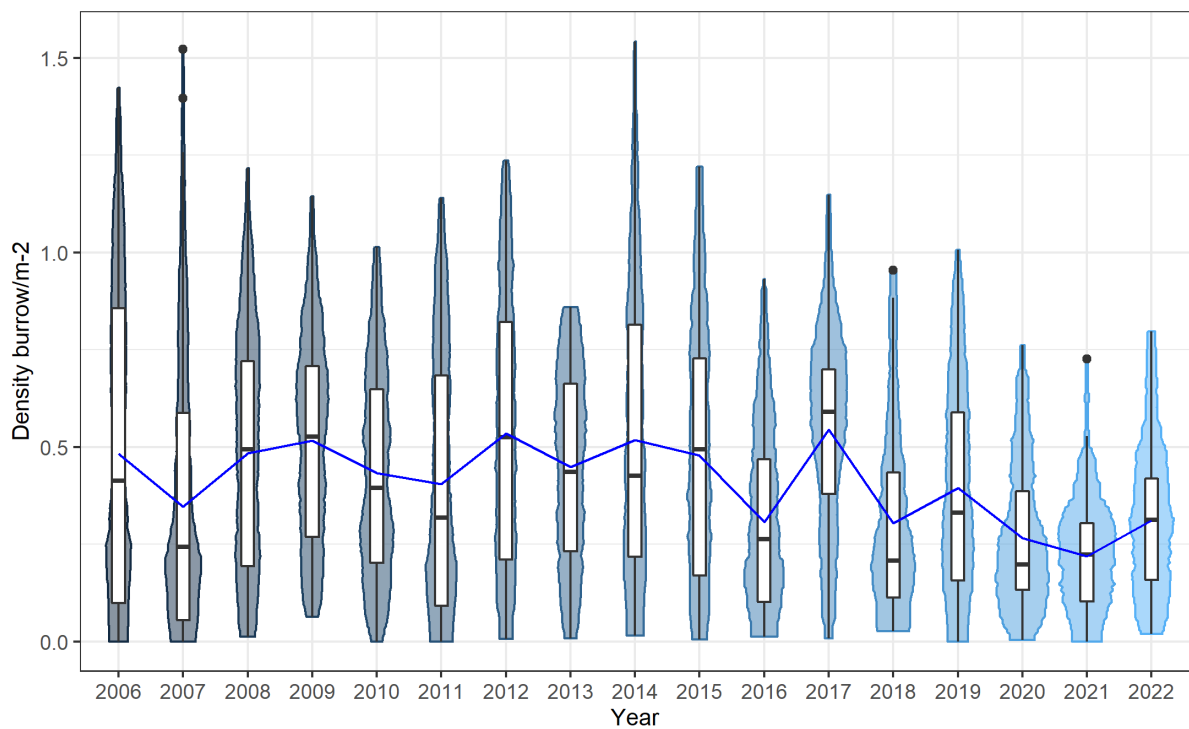


Figure 6: FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006 -2022. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers.

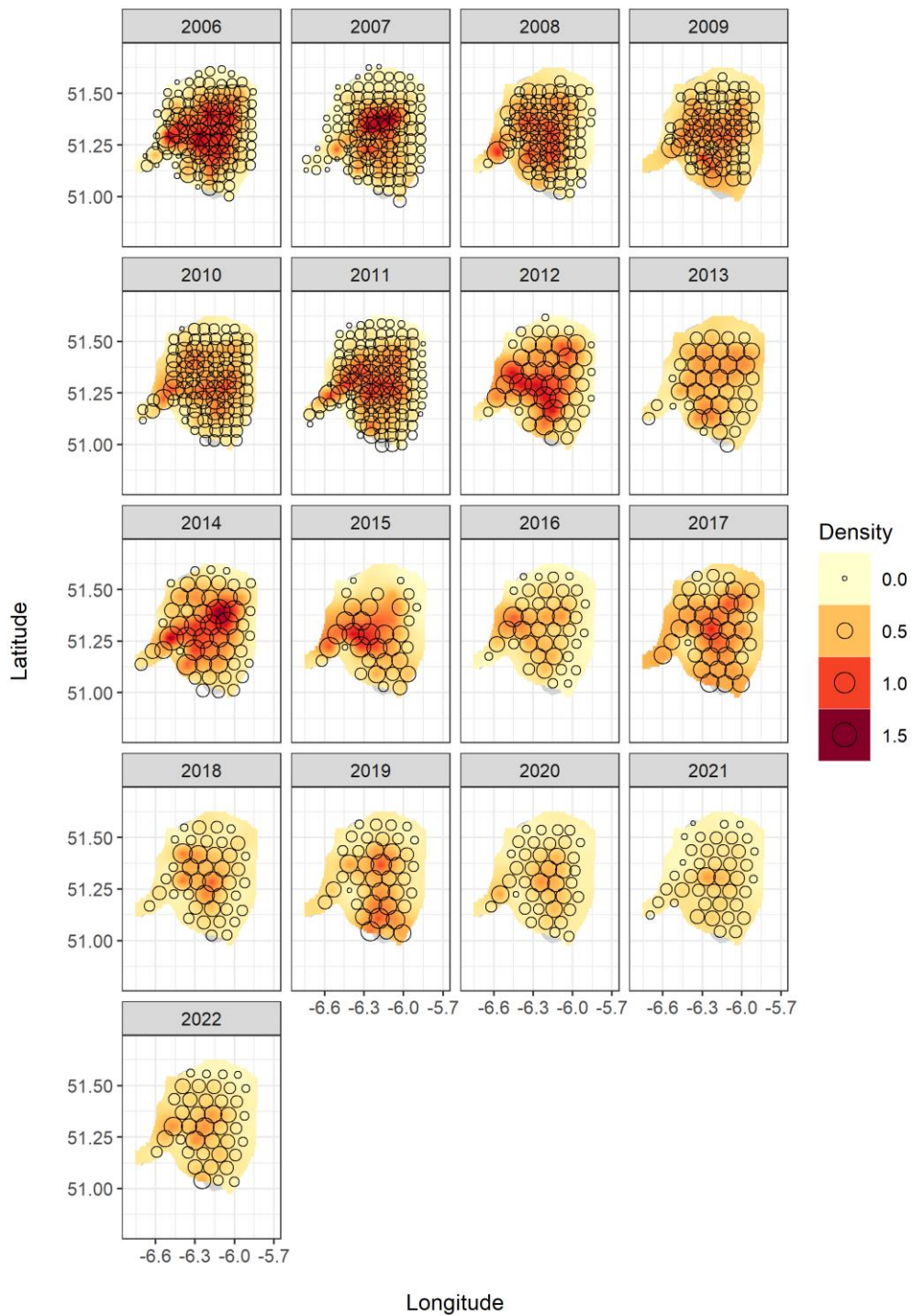


Figure 7: FU22 Smalls grounds: Contour plots of the kriged density estimates by year from 2006 (top left) – 2022 (bottom left).

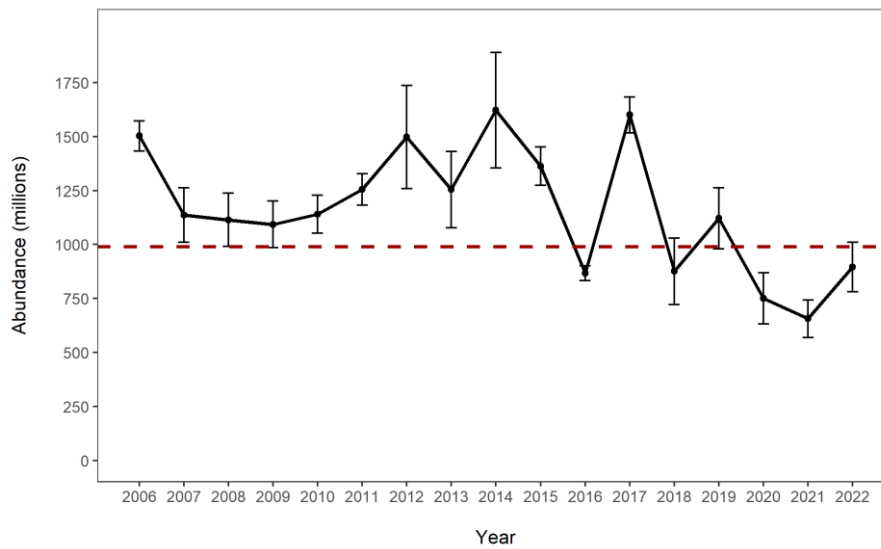


Figure 8: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows). The error bars indicate the 95% confidence intervals and B_{trigger} is dashed line.

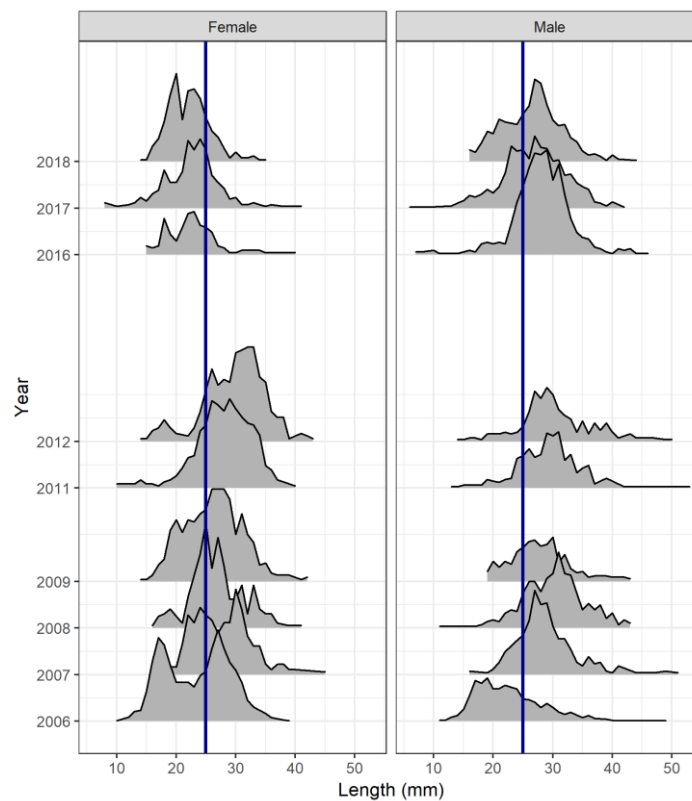


Figure 9: FU22 Smalls grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2018 UWTV surveys (except years 2010, 2013 - 2015, 2019 to 2022). Blue line indicates minimum conservation reference size 25 mm carapace length.

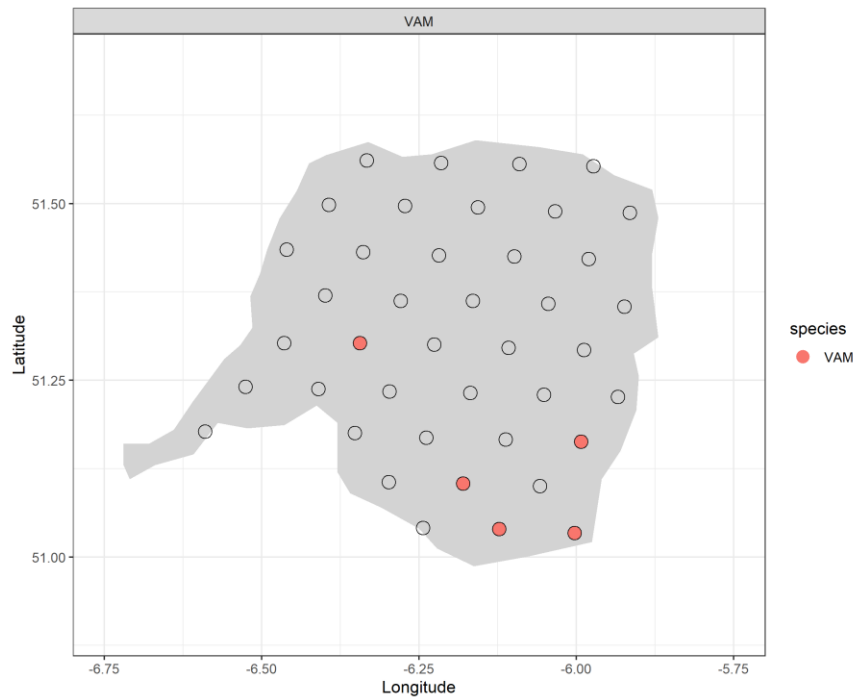


Figure 10: FU22 Smalls grounds: 2022 stations where *Virgularia mirabilis* (VAM) were identified. Closed circles indicated presence and open circles denotes TV stations with no sea-pen observations.

Table 1: FU22 Smalls grounds: Overview of geostatistical results from 2006-2022.

Year	Number of stations	Mean Density adjusted (burrow/m ²)	Domain Area (Km ²)	Geostatistical Abundance adjusted (millions of burrows)	95% confidence interval (millions of burrows)	CV on Burrow estimate (%)
2006	100	0.49	2962	1503	70	2.4
2007	107	0.37	2955	1136	126	5.7
2008	76	0.36	2698	1114	123	5.6
2009	67	0.36	2824	1093	108	5.0
2010	90	0.37	2861	1141	88	3.9
2011	107	0.41	2881	1256	72	2.9
2012*	47	0.49	2934	1498	239	8.1
2013*	41	0.41	2975	1254	177	7.2
2014*	52	0.53	2970	1622	268	8.4
2015*^	40	0.49	3064	1363	180	7.0
2016*	41	0.31	3063	866	112	6.6
2017*	40	0.55	3063	1600	153	4.9
2018*	42	0.31	3063	876	154	9.0
2019*	41	0.4	3063	1121	141	6.4
2020*	40	0.27	3063	750	118	8.0
2021*	42	0.23	3063	656	87	6.7
2022*	41	0.31	3063	895	115	6.5

*reduced randomised isometric grid

^ In 2015 seven of the stations were filled in with an estimate based on the mean density of historical stations within 2 nmi of the planned station.

Table 2: FU22 Smalls grounds: Inputs to catch scenarios table.

Year	Low	UWTV abundance estimate	High	Landings in number	Total discards in number *	Removals in number	Harvest rate (by number)	Landings	Total discards *	Discard rate (by number)	Dead discard rate (by number)	Mean weight in landings	Mean weight in discards
2003				95	68	146		2065	720	41.5	34.7	21.70	10.65
2004				71	13	80		1828	202	15.6	12.2	25.87	15.39
2005				119	129	216		2533	1648	51.9	44.7	21.24	12.81
2006	1433	1503	1573	100	45	134	8.9	1761	454	31.1	25.3	17.58	10.06
2007	1010	1136	1262	165	181	301	27	2950	1906	52.3	45.1	17.86	10.54
2008	991	1114	1237	144	26	163	14.6	3090	289	15.3	12.0	21.52	11.11
2009	985	1093	1201	92	33	117	10.7	2185	371	26.4	21.2	23.75	11.25
2010	1053	1141	1229	122	45	155	13.6	2714	636	26.8	21.5	22.28	14.28
2011	1184	1256	1328	60	13	70	5.6	1636	196	18.0	14.1	27.29	14.93
2012	1259	1498	1737	120	31	144	9.6	2618	347	20.7	16.3	21.75	11.07
2013	1077	1254	1431	94	40	124	9.9	2257	497	30.0	24.3	24.13	12.39
2014	1354	1622	1890	100	33	125	7.7	2526	460	25.0	20.0	25.22	13.78
2015	1183	1363	1543	114	44	147	10.8	2350	450	28.0	22.6	20.59	10.14
2016	754	866	978	160	54	200	23	3329	519	25.1	20.0	20.79	9.70
2017	1447	1600	1753	164	39	194	12.1	3560	424	19.2	15.2	21.66	10.84
2018	722	876	1030	98	30	121	13.8	1974	336	23.7	18.9	20.19	11.03
2019	980	1121	1262	81	19	95	8.5	2083	262	19.2	15.1	25.76	13.67
2020^	632	750	868	59	21	76	10.1	1518	288	26.5	21.3	25.56	13.43
2021	569	656	743	61	11	70	10.7	1616	149	15.6	12.2	26.32	13.13
2022	780	895	1010										

^ Values updated due to minor revisions in reported landings.

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

Variable	Value	Notes
Stock abundance (2023)	895	UWTV survey 2022; individuals in millions
Mean weight in projected landings	25.9	Average 2019–2021 in grammes
Mean weight in projected discards	13.4	Average 2019–2021 in grammes
Projected discard rate	20.4	Average 2019–2021; percentage by number of the total catch
Discards survival rate	25	Percentage by number of the discards

Table 4: Catch advice and scenarios for 2023; Discarding assumed to continue at recent average. All weights are in tonnes.

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	% harvest rate*	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD	for PL + PDD	
ICES advice basis							
MSY approach: $F_{MSY} \times$ Stock abundance 2023 / $MSY B_{trigger}$	2548	2473	2248	225	75	11.6	103
Other scenarios							
$F_{MSY lower} \times$ Stock abundance 2023 / $MSY B_{trigger}$	2025	1965	1786	179	60	9.2	61
F_{MSY}	2818	2735	2486	249	83	12.8	124
$F_{MSY lower}$	2245	2179	1981	198	66	10.2	79
$F_{MSY upper}^{***}$	2818	2735	2486	249	83	12.8	124
F_{2021}	2347	2277	2070	207	69	10.7	87

* By number.

** Advice values for 2023 are relative to the 2022 advice (F_{MSY} advice of 1257 tonnes).

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