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ECOSYSTEM OBSERVATION STEERING GROUP

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REF ACOM AND SCICOM

Report of the Working Group on Nephrops Surveys (WGNEPS)

6-8 November

Lorient, France

ICES CIEM
International Council for the Exploration of the Sea
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Executive summary

The Working Group on *Nephrops* Surveys (WGNEPS), until 2012 known as SGNEPS, is the international coordination expert group for *Nephrops* Underwater Television (UWTV) and trawl surveys within ICES areas and in a preliminary and exploratory way in some Geographical subareas (GSA) in the Mediterranean and has a quality assurance and development role.

In the current 3-year period (2016-2018), an ICES Cooperative Research Report #340 on "Using underwater television surveys to assess and advise on *Nephrops* stocks" has been published, and a draft version of the manual for *Nephrops* Underwater TV Surveys for inclusion in the Series of ICES Survey Protocols (SISP) has been completed.

Updates of 20 *Nephrops* UWTV and 3 *Nephrops* trawl surveys conducted by 12 different countries (Croatia, Denmark, France, Iceland, Ireland, Italy, Portugal, Spain, Sweden, UK England, UK Northern Ireland, UK Scotland) covering in total 23 *Nephrops* functional units were presented and reviewed annually during the WGNEPS meetings. Coordination between surveys across countries and laboratories in particular in respect to *Nephrops* burrow identification and the application of new technologies for recording and analysing video footages were carried out at the annual meetings and during two separate workshops in 2017 and in 2018. The working group evaluated whether the interpretation of UWTV survey results could be improved by examining experimental and fieldwork on *Nephrops* behaviour and burrow emergence and similar species in waters that are not regularly covered by the surveys coordinated by WGNEPS (e.g. Greece and New Zealand). R-scripts for checking data quality and presentation of survey results have been developed and distributed among the WG members. Additionally, protocols for reporting survey results have been adopted for further standardization and the structure and requirements for a database holding the UWTV survey data have been defined. This allows WGNEPS to ensure data quality as well as to endorse proposed changes to the design of the *Nephrops* UWTV and trawl surveys.

1 Administrative details

Working Group name

WGNEPS – Working Group on *Nephrops* Surveys

Year of Appointment within the current cycle

2016

Reporting year within the current cycle

3

Chair(s)

Adrian Weetman, Marine Scotland, UK

Kai Wieland, DTU Aqua, Denmark

Meeting venue(s) and dates

7–8 November 2016, Reykjavik, Iceland (19 participants)

28 November – 1 December 2017, Heraklion, Greece (19 participants)

6 – 8 November 2018, Lorient, France (18 participants)

WGNEPS attendees 2018 in Lorient (8 WG members joined via Skype)

2 Terms of Reference

A **Working Group on *Nephrops* Surveys** (WGNEPS), chaired by Adrian Weetman, Scotland*, and Kai Wieland*, Denmark, will work on ToRs and generate deliverables as listed in the Table below.

	MEETING DATES	VENUE	REPORTING DETAILS	COMMENTS (CHANGE IN CHAIR, ETC.)
Year 2016	7-11 November	Reykjavík, Iceland	Interim report by 31 January 2017 to SSGIEOM	
Year 2017	28 November-1 December	Heraklion, Greece	Interim report by 26 January 2018 to EOSG	
Year 2018	6-8 November	Lorient, France	Final report by 14 December to EOSG	

ToR descriptors

TOR	DESCRIPTION	BACKGROUND	SCIENCE PLAN TOPICS ADDRESSED	DURATION	EXPECTED DELIVERABLES
	Review SISP guidelines	EOSG have developed guidelines for the SISPs, and it is important to update those guidelines to reflect the use of the protocol by the EGs	28,31	Year 1	Review the current SISP guidelines.
a	To review any changes to design, coverage and equipment for the various *Nephrops* UWTV surveys.	To ensure surveys used by WKNEPH, WGCSE, and WGNSSK are fit for purpose.	28,31	Recurrent annual update	Survey summary including and description of alterations to the plan, to relevant assessment-WGs (WKNEPH, WGCSE, WGNSSK,) and SCICOM. Planning of the upcoming surveys for the survey coordinators and cruise leaders, and update the SISP accordingly.
b	To review the design, coverage, results and uses of *Nephrops* trawl surveys in consultation with WGISDAA.	There are trawl surveys for *Nephrops* in some area and trawling activity also takes place with UWTV surveys. These activities need rewiew and coordination.	28,31	Recurrent annual update	Survey summary including and description of alterations to the plan, to relevant assessment-WGs (WKNEPH, WGCSE, WGNSSK, WGHMM,) and SCICOM. Planning of the upcoming surveys for the survey coordinators and cruise leaders, and update the SISP accordingly.

c	To review video enhancement, video mosaicking, automatic burrow detection and other new technological developments.	WGNEPS should periodically review emerging technologies that might improve survey methodologies.	28	Recurrent annual update	To update the SISP based on conslusions. Other publications when appropriate.
e	Discuss the utility of UWTV and trawl *Nephrops* surveys as platforms for the collection of data for OSPAR and MFSD indicators.	*Nephrops* UWTV surveys have a role in relation to benthic habitat monitoring and the collection of other environmental and ecosystem variables.	9	Year 2	To update the SISP based on conclusions
f	Develop an international database which will hold burrow counts, ground shape files and other data associated with UWTV surveys. Develop an international database on trawl surveys.	There is a need to centralize UWTV data in a single international database. Ensure data are avaibale externally.	25	Year 2/3	ICES database
g	Review of existing datasets to evaluate possible factors affecting (i.e. currents, light, etc.) burrow emergence.	Recent behaviour aspects have been investigated in the laboratory. Important to investigate correlation with field data.	25	Year 2/3	Review paper
h	Developing R scripts for UWTV survey data processing including functions to QC, analyse and visualize data, and interface the tools with the database (ToR f).	Improving standarisation of data QC and data processing. Support new developing surveys on data analysis.	25,27	Year 3	Document and R packages for UWTV survey data.

3 Summary of work plan

Year 1	The main task will be to carry out a burrow counting training workshop at a European level, this will take place in Reykjavík, Iceland. This WG will be extended for 1 day to accommodate the training course in the same week. Around 2 days will be allocated to review any changes to design, coverage and equipment for the various *Nephrops* UWTV/trawl surveys and to review video enhancement, video mosaicking, automatic burrow detection and other new technological developments and the remaining 3 days will be allocated to the burrow counting training workshop. The facilities and equipment will be provided by the Marine Research Institute in Iceland; additional equipment might be provided by other Institutes if required.
Year 2	TOR a, b and c will be addressed annually. This year will focus on exploring the utility of UWTV and trawl *Nephrops* surveys as platforms for the collection of data for OSPAR and MFSD indicators (ToR e). Additionally, ToRs f and g will also be addressed and plans for ToR h will be made. Decision will be made in relation to the need of further training on burrow counting. If necessary, this will take place on year 3.
Year 3	TOR a, b, and c will be addressed annually. Work will focus on ToRs f, g, and h as well as reviewing any relevant changes to survey procedures. SISP will be updated accordingly.

4 Summary of achievements of the WG during 3-year term

- Reviewed changes to the design, coverage and equipment for the various *Nephrops* UWTV and trawl surveys.
- Reviewed outcomes from benchmarks for *Nephrops* stocks with respect to the quality of the *Nephrops* survey data used in advice.
- Applied recent technology developments such as HD cameras and fibre optic cables in *Nephrops* UWTV surveys.
- Updated the process to create video mosaics from UWTV survey footages.
- Completed the Cooperative Research Report "Using underwater surveys to assess and advise on *Nephrops* stocks (CRR #340).
- Defined data structure and requirements for the UWTV database for *Nephrops*.
- Developed R-scripts for data processing and quality control of *Nephrops* survey data.
- Considered the results of experimental and fieldwork on *Nephrops* burrow emergence to improve the interpretation of the survey results.
- Reviewed the outcomes of *Nephrops* burrow counting workshops in 2016 and 2018 to improve the guidelines for the survey data analysis.
- Completed a final draft of the manual for *Nephrops* Underwater TV Surveys for the Series of ICES Survey Protocols (SISP).

5 Final report on ToRs, workplan and Science Implementation Plan

5.1 ToR a and ToR b. To review any changes to design, coverage, and equipment for the various *Nephrops* UWTV surveys, and to review the design, coverage, results and uses of *Nephrops* trawl surveys in consultation with WGISDAA.

This section provides an update for the various UWTV and trawl surveys currently undertaken on a regular basis in the North Sea and Mediterranean (Figure 5.1.1). This includes any modifications done on survey design, coverage, and procedures. Updates are provided by country with conclusions and respective recommendations. An overview over the timing of the survey conducted in 2018 and planned for 2019 is given in section 5.1.11.

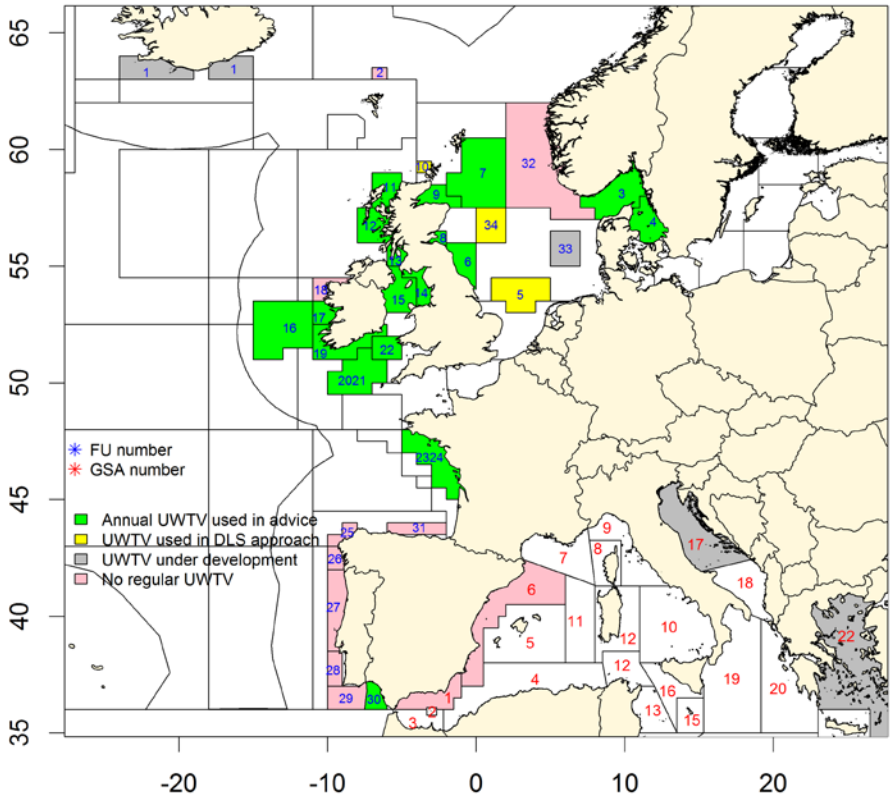


Figure 1.1 ***Nephrops*** **UWTV survey coverage in 2017 (FU: Functional Unit, GSA: Geographical Sub Area, DLS: Data Limited Stock).**

5.1.1 Ireland

(Jennifer Doyle, Mikel Aristegui)

Overview of the existing surveys:

Since 2012 Ireland has modified sampling intensity and increased survey coverage based on the recommendations of SGNEPS in 2012 (ICES, 2012). The numbers of stations in FU15, FU17 and FU22 were reduced since 2012 to allow for survey development in FU16, FU19 and FU2021. The total numbers of stations for 2018 remains broadly similar ~300 to previous years (Figure 5.1.1.1). 100% coverage of all the *Nephrops* grounds was achieved in 2018. There were no significant changes to the equipment or survey design for the surveys in 2018 and all image data collected is in the standard analogue format in 2018. The CVs for surveys where sampling intensity was reduced either had no or minor decreases in relative precision and are well below the 20% limit as recommended by SGNEPS 2012 for precision (Table 5.5.1.1). In 2018 the survey count data for all FUs were screened to check for any discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a minimum threshold of 0.5 as recommended by the SISP (in draft) for FU 20-21 and FU 19 and 0.6 for FU 17 and FU 22. All burrows were time-stamped for FU 16 in 2018. The adjusted mean density for each station in ICES Subarea 7 is presented in Figure 5.5.1.2 and it shows the general overall pattern which is mainly higher densities observed in FU15 and lower densities in FU16. There was an overall decrease in observed burrow densities in the Celtic Sea and Irish Sea *Nephrops* grounds in 2018 compared to last year.

Table 5.5.1.1. 2018 UWTV mean adjusted density, abundance estimate, CV (relative standard error) and Lin's Concordance Correlation Coefficient (CCC) threshold by Functional Unit.

UWTV Survey	Mean density adjusted (burrow/m²)	Final Abundance Estimate (millions individuals)	CV (Relative standard error)	Lin's Concordance Correlation Coefficient Threshold to screen survey Counts
FU16	0.16	1117	4%	NA time-stamped
FU17 Aran Grounds only	0.40	488	3%	0.6
FU19	0.09	176	15%	0.5
FU2021	0.27	2721	4%	0.5
FU22	0.31	876	9%	0.6

In recent years, there has been a good flow of staff exchange on UWTV surveys in ICES Subarea 7 such as the collaborative UWTV survey in the Irish Sea (FU14 and FU15). In 2018, staff from Ifremer and AFBI participated on two Irish surveys. Inter institute exchange is important as it promotes protocol and technology transfer.

The individual UWTV survey reports and further details of the survey design, numbers of stations and data processing are available from the Marine Institute Open Access Repository at http://oar.marine.ie/handle/10793/59.

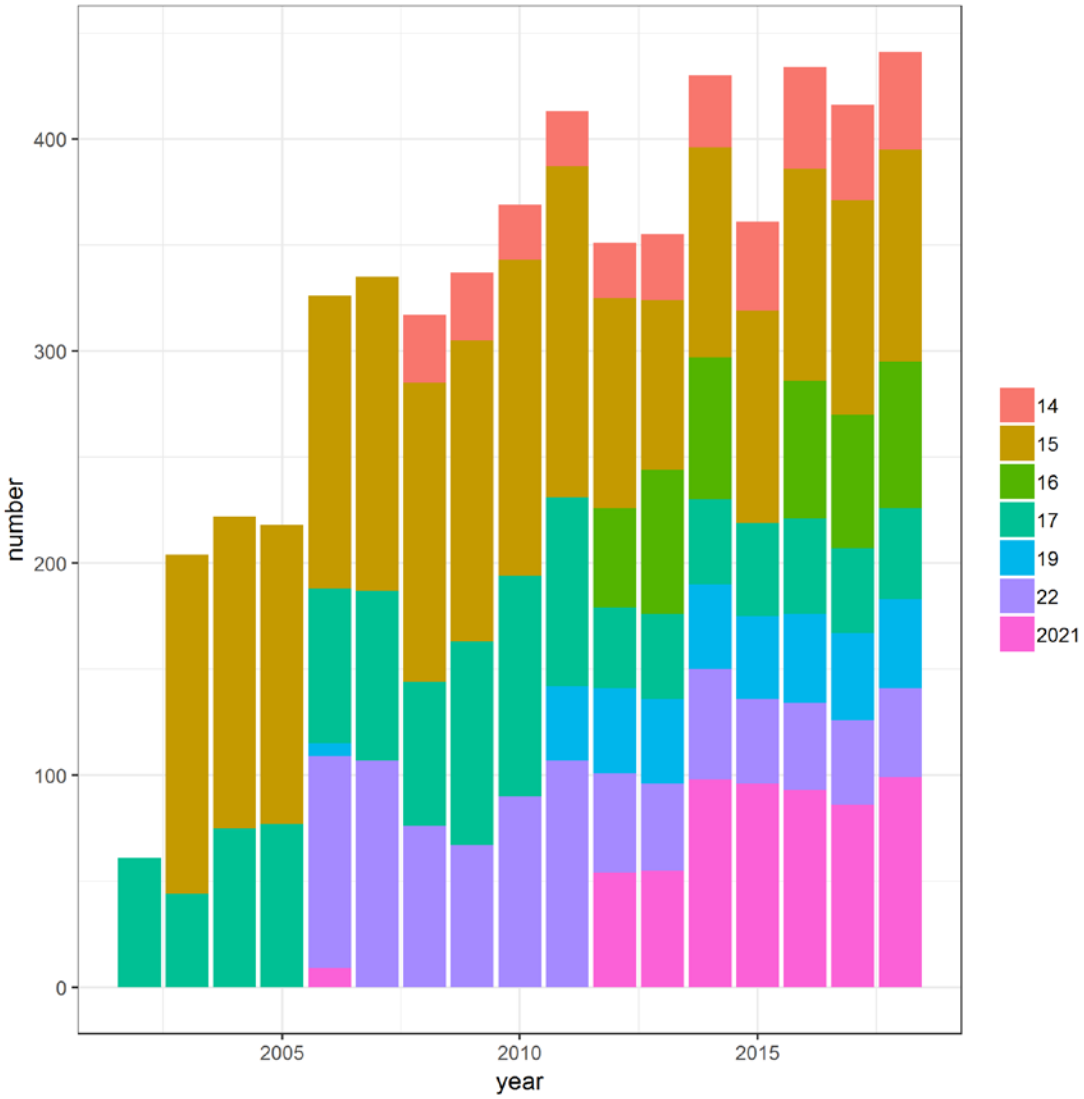


Figure 5.5.1.1. Time-series of the total number of UWTV stations carried out by Ireland in each Functional Unit. Stations in FU 14 and FU 15 are carried out in collaboration with AFBI in UK-NI and CEFAS UK E&W.

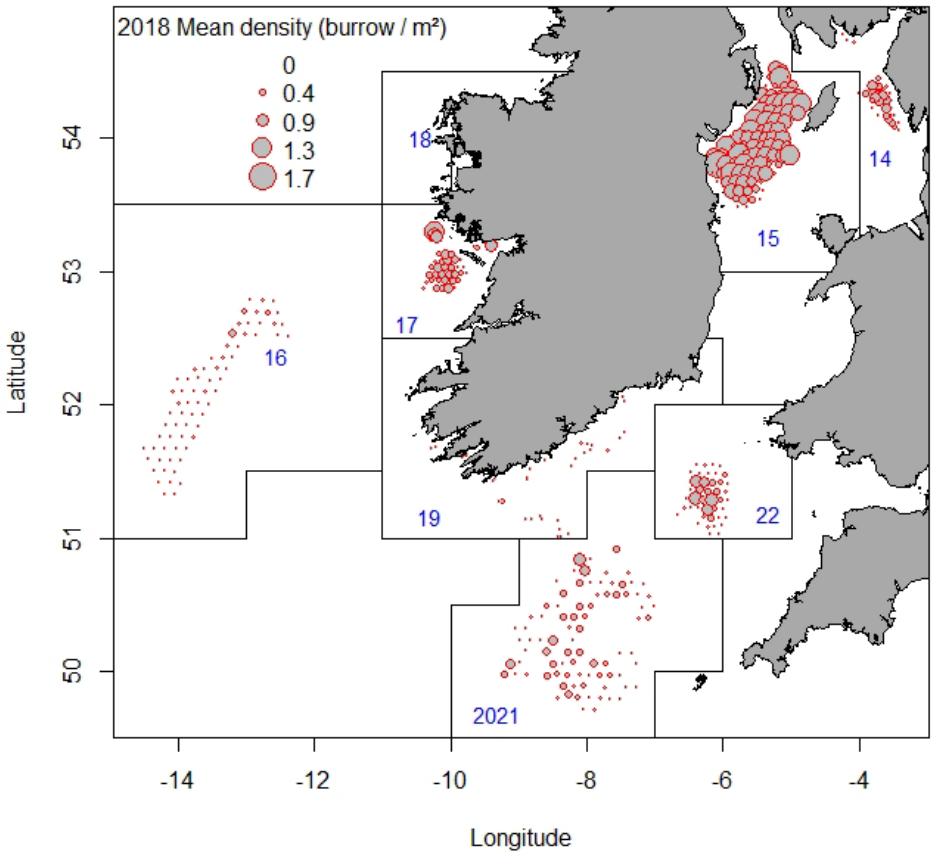


Figure 5.5.1.2. 2018 Mean adjusted density estimates (burrow/m²) by station for *Nephrops* grounds in ICES Subarea 7.

UWTV Survey FU16: Porcupine Banks.

This is the sixth underwater television on the 'Porcupine Bank *Nephrops* grounds' ICES assessment area; Functional Unit 16 in 2018. The survey was multidisciplinary in nature collecting UWTV, CTD and other ecosystem data. In total 69 UWTV stations were successfully completed in a randomized 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 km². The 2018 abundance estimate was 31% higher than in 2017. The three species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangularis* and *Pennatula phosphorea,* were all observed during the survey. Trawl marks were also observed on 33% of the stations surveyed. A combined violin and box plot of the observed burrow densities is presented in Figure 5.5.1.3. 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.

[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).

Further details on this survey available at: http://hdl.handle.net/10793/1379

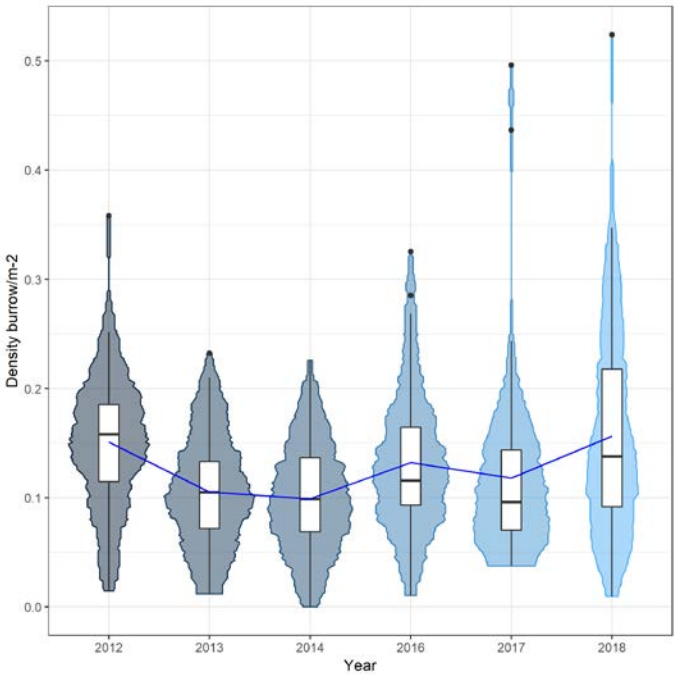


Figure 5.5.1.3. Porcupine Bank 2018. Violin and box plot a of adjusted burrow density distributions by year from 2012-2018. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No UWTV survey in 2015.

UWTV Survey FU17: Aran grounds, Galway Bay and Slyne Head *Nephrops* grounds.

In 2018 the seventeenth annual underwater television on the Aran, Galway Bay and Slyne head *Nephrops* grounds, ICES assessment area; Functional Unit 17 was successfully carried out. The survey was multidisciplinary in nature collecting UWTV, fishing, CTD and other ecosystem data. In 2018 a total of 43 UWTV stations were successfully completed, 33 on the Aran Grounds, 5 on Galway Bay and 5 on Slyne Head patches. The mean burrow density observed in 2018, adjusted for edge effect, was medium at 0.40 burrows/m². The final krigged burrow abundance estimate for the Aran Grounds was 488 million burrows with a CV (relative standard error) of 3%. The final abundance estimate for Galway Bay and Slyne Head was 33 million in both grounds with CVs of 17% and 12% respectively. The total abundance estimates have fluctuated considerably over the time-series. The 2018 combined abundance estimate was a 37% increase compared to in 2017 and at 554 million burrows and is above the MSY $B_{trigger}$ reference point (540 million burrows). *Virgularia mirabilis* was the only sea-pen species observed on the UWTV footage. Trawl marks were present at 9% of the Aran stations surveyed. A combined violin and box plot of the observed burrow densities from 2006 to 2018 is presented in Figure 5.5.1.4. This shows relatively large interannual variation in mean, median and density ranges over time. Density increased in first three years of the time-series but then declined significantly in 2006. Since then there has been a gradual downward trend. The mean and median density has increased in 2018 to levels observed in 2015. It has been very noticeable since 2011 that there was a substantial reduction in density throughout the ground with no high density (> 0.7/m²) observed. Figure 5.5.1.5 is the violin plot of

densities for the Galway Bay and Slyne Head *Nephrops* grounds which also shows relatively large interannual variation in mean, median and density ranges over time.

Further details on this survey available at: http://hdl.handle.net/10793/1374

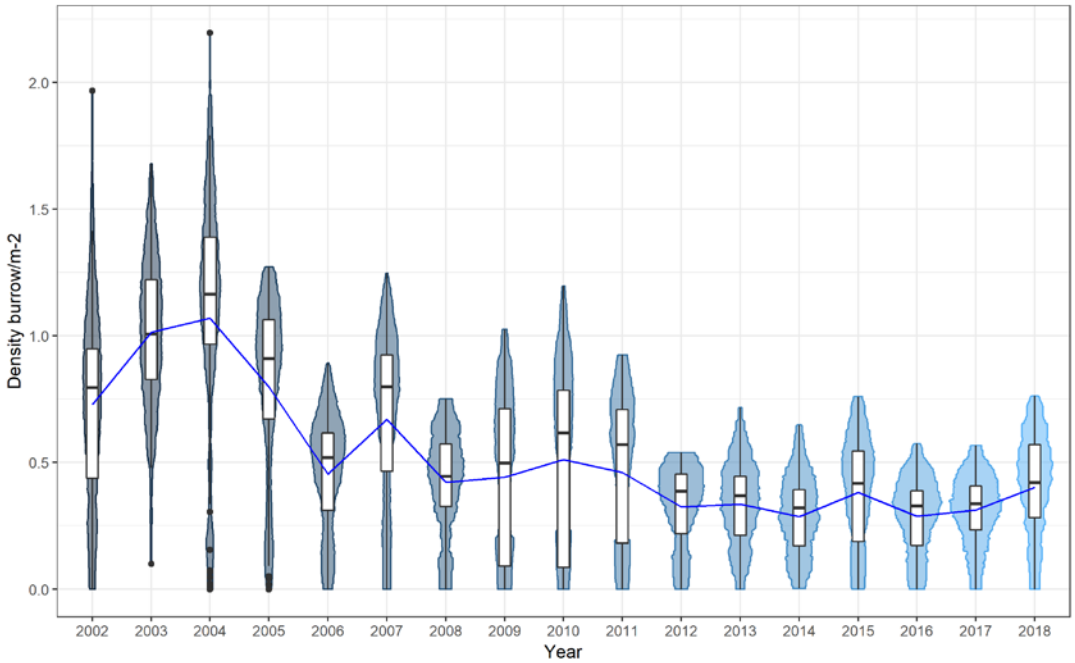


Figure 5.5.1.4. FU17 Aran grounds: Violin and box plot of adjusted burrow density distributions by year from 2002-2018. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

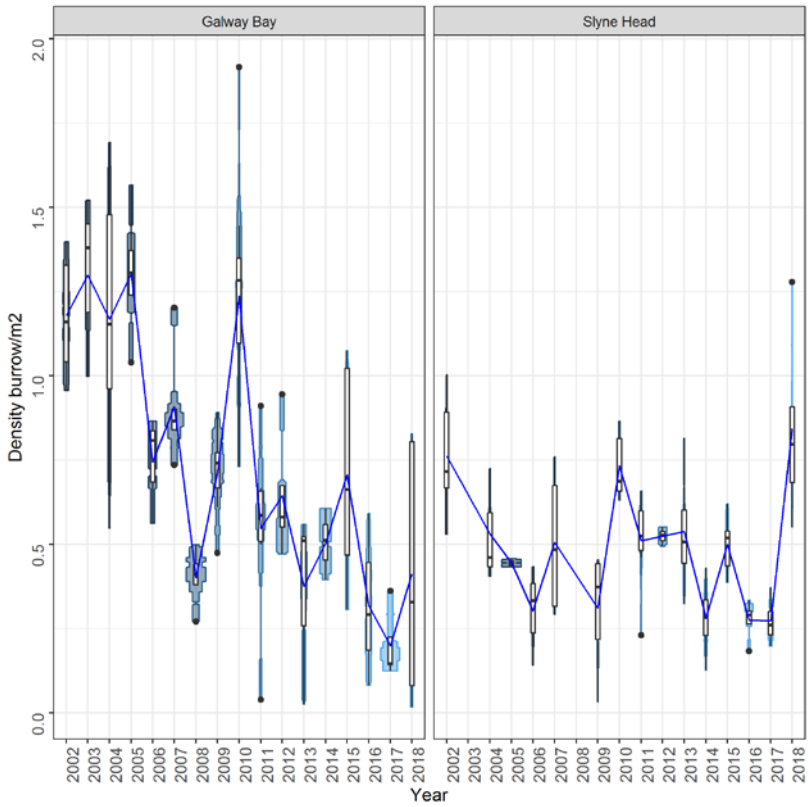


Figure 5.5.1.5. FU17 Galway Bay and Slyne Head: Violin and box plot of adjusted burrow density distributions by year from 2002-2018. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

UWTV Survey FU19. South and Southwest coast of Ireland.

This was the ninth survey of the various *Nephrops* patches in Functional Unit 19 in 2018. The survey was multidisciplinary in nature collecting UWTV, multibeam and other ecosystem data. In 2018 a total 42 UWTV stations were successfully completed. The mean density estimates varied considerably across the different patches. The 2018 raised abundance estimate was a 65% decrease from the 2017 estimate and at 176 million burrows is below the MSY $B_{trigger}$ (430 million). One species of sea pen was observed; *Virgularia mirabilis,* which has been observed on previous surveys of FU19. Trawl marks were observed at 36% of the stations surveyed. The adjusted burrow densities for each *Nephrops* patch from 2006 to 2018 are shown in Figure 5.5.1.6 as a violin and box plot. For the most grounds the observed densities were lower in 2018 compared to previous years.

Further details on this survey available at: http://hdl.handle.net/10793/1375 .

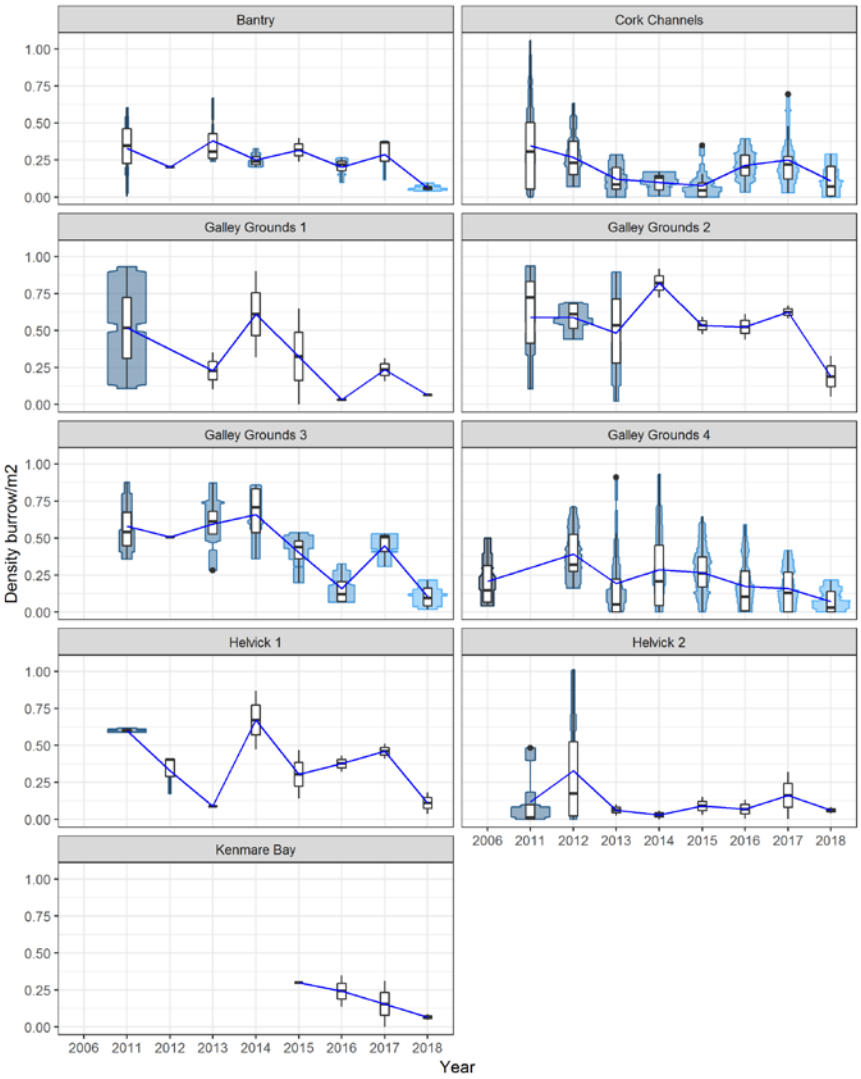


Figure 5.5.1.6. FU19 grounds: Violin and box plots of adjusted burrow density distributions by year for 2006-2018 for each ground. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No TV survey from 2007 – 2010.

UWTV Survey FU20-21: Labadie, Jones and Cockburn Banks.

In February 2014 WKCELT concluded that full survey coverage was needed before *Nephrops* in FU20-21 could be moved into a full UWTV survey category for assessment and advice (ICES, 2014). The 2018 survey achieved full coverage of the stock area for the fifth successive time. Area of this ground is calculated at 10 014 km² which is the largest *Nephrops* ground in ICES area 7 (ICES, 2014). The 2018 survey was multidisciplinary in nature collecting UWTV, and other ecosystem data. A total of 96 UWTV stations were completed at 6 nm intervals over a randomized isometric grid design. The mean burrow density was 0.27 burrows/m² compared with 0.44 burrows/m² in 2017. The 2018 geo-statistical abundance estimate was 2.7±0.006 billion, a 39% decrease on the abundance for 2017, with a CV of 4% which is well below the upper limit of 20% recommended by SGNEPS in 2012 (ICES, 2012). High densities were observed throughout the ground, and also close to boundaries. One species of sea-pen (*Virgularia*

mirabilis) were recorded as present at the stations surveyed. Trawl marks were observed at 33% of the stations surveyed. The adjusted burrow densities from 2013 to 2018 are shown in Figure 5.5.1.7 as a combined violin and box plot. These show that density has decreased in 2018 from 2017. There were two observations of high densities (>0.7/m²) while the majority were in the range of 0.15 to 0.6/m². The 2018 mean adjusted density of 0.27 burrows/m² is the second highest in the time-series to date and was 40% lower than the 2017 estimate of 0.44 burrows/m².

Further details on this survey available at: http://hdl.handle.net/10793/1377.

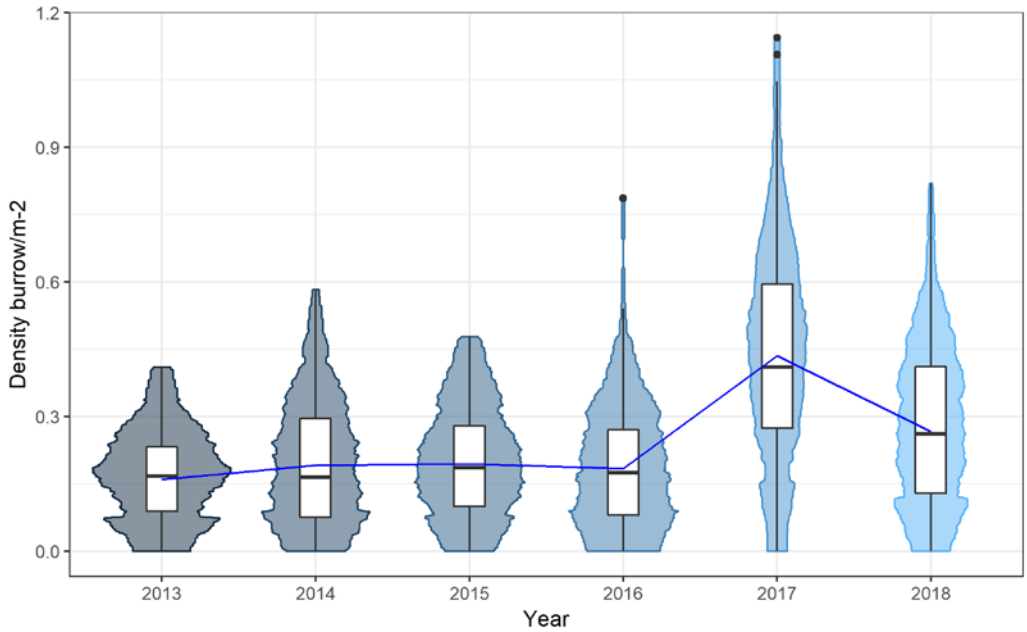


Figure 5.5.1.7.
FU20-21 grounds: Violin and box plot of adjusted burrow density distributions by year from 2013-2018. The blue line indicates the mean density over time. The horizontal blacks line represents medians, white boxes the inter quartile ranges, the black vertical lines are the range and the black dots are outliers.

Review of survey count data for 2016 and 2017 for FU20-21

The substantial change in *Nephrops* abundance estimates (135% increase) for FU20-21 from 2016 to 2017 (from 1,879 million to 4,428 million) was discussed at the Working Group for the Celtic Seas Ecoregion (WGCSE) 2018 in May. WGCSE recommended that a review of the footage from both 2016 and 2017 should be carried out to check if this change was the result of a year effect on the counting behaviour.

All the analyses carried out by the Marine Institute are fully documented in an R-markdown document (Annex 7).

The station selection procedure for the review is summarized here. Only stations with more than 15 burrows were preselected. The stations with highest counts were selected for the review (two outliers from each year); additionally, a random 20% from the other preselected stations were selected (14 stations from each year). This process resulted in a total of 16 stations from each year to be reviewed.

The review process was conducted at sea during the FU20-21 2018 survey. As standard procedure, all counts were undertaken once the reference footage was passed by all the counters. The 32 review stations were interspersed with the current 2018 stations and distributed equally among the 6 counters. Each station was counted by two reviewers independently.

All review count data were screened to check for any unusual discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a threshold of 0.5. Lin's CCC measures the ability of counters to exactly reproduce each other's counts on a scale of 1 to -1, where 1 is perfect concordance (Lin, 1989). When a station did not pass this test, a third review was undertaken. For those stations that did not pass the threshold it was deemed appropriate to use the average of the three reviewers for the analysis.

The initial results showed a low increase in the review counts for 2016 stations comparing them with the survey counts (3.8% increase), and a high decrease in the review counts for 2017 stations comparing them with the survey counts (30.8% decrease). Next the review count data were swapped with the survey count data and abundance was calculated for both years using the "RGeostats" package (Renard D. *et al.*, 2015), following the same procedure that was carried out in those years previously. The geo-statistical results showed an increase of 4.6% in 2016 abundance estimate (from 1,879 million to 1,966 million), and a decrease of 4% in 2017 abundance estimate (from 4,428 million to 4,250 million). The geo-statistical CVs were in the order of 3.7% to 4.4%, which are well below the upper limit recommendation of 20% (ICES, 2012). The result of this review process underlines that the change in abundance is not down to some year effect on the counting behaviour.

The SISP for Nephrops UWTV surveys will include guidelines on quality control where there are large unexplained fluctuations between abundance estimates from previous years. In that it is recommended to review 20% of the survey stations, and when the partial review differs more than 20% from the survey counts a full review of the survey should be considered (ICES, in prep.).

UWTV Survey FU22: The Smalls.

This was the thirteenth annual underwater television survey on the 'Smalls grounds' ICES assessment area; Functional Unit 22 in 2018. The survey was multidisciplinary in nature collecting UWTV, CTD and other ecosystem data. A total of 42 UWTV stations were surveyed successfully (good quality video footage), carried out over an isometric grid at 4.5nmi or 8.3km intervals. The precision, with a CV of 9%, was well below the upper limit of 20% recommended by SGNEPS (ICES, 2012). The 2018 abundance estimate was 45% lower than in 2017 and at 876 million is below the MSY $B_{trigger}$ reference point (990 million). Two species of sea pens were recorded as present at the stations surveyed: *Virgularia mirabilis* and *Pennatula phosphorea*. Trawl marks were observed at 55% of the stations surveyed. Nine beam trawl tows were carried out, providing important data on the benthic communities and size structure of the *Nephrops* population. A combined violin and box plot of the observed burrow densities is presented in Figure 5.5.1.8. This shows that median and mean burrow densities are similar in most years. The inter-quartile range is between 0.2 - 0.7 in most years. However in 2018, as in 2016, this inter-quartile range is in the region of 0.1 - 0.4. In 2018 the mean adjusted burrow density was 0.31 burrows/m^2. No adjusted burrow densities > 1.0 burrows/m^2 were observed in 2018.

Further details on this survey available at: http://hdl.handle.net/10793/1376.

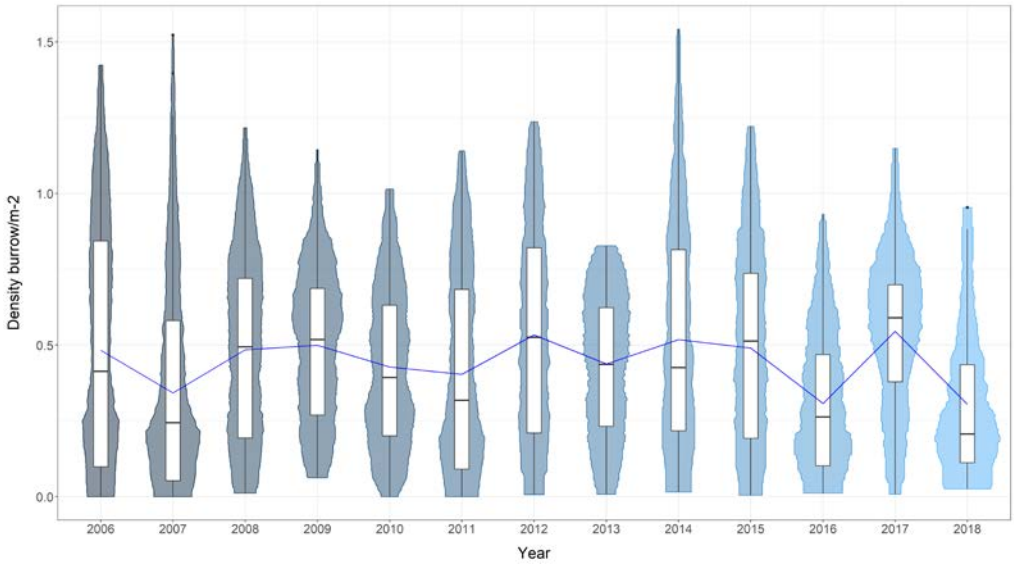


Figure 5.5.1.8. FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006-2018. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers.

UWTV Survey Data Management.

On completion of each UWTV survey the data (such as: counts, distance over ground, ship and sledge tracks and descriptive data) which are held in MS Access local database are quality controlled using in house "R"-scripts. When the data has passed quality control procedures it is then uploaded to the MI SQL server UWTV database. Since 2017 SQL server script queries are used to calculate the final adjusted densities and extract the TV survey data for the final analysis.

Geo-statistical analysis was carried out using RGeostats package (Renard D., *et al.*, 2015) and is available as an R markdown document for UWTV surveys in FUs 16, 17, 20-21 and 22. Analysis for FU19 is also available in R markdown document.

Sediment Sampling.

In the early years of the TV surveys on the Aran (FU 17) and Smalls (FU 22) *Nephrops* grounds an intensive sediment sampling programme was carried out. The samples were processed by particle size analyses (PSA). These sediment data have been used to define the extent of each of these *Nephrops* grounds as part of the ICES benchmark stock process (ICES, 2015, Leocádio, *et al.*, 2018).

In 2018 during the UWTV surveys in the Celtic Sea (FU 19 and FU 20-21) sediment sampling was carried out using the Shipex grab when time allowed. This was undertaken as part of an in-house cross collaboration project. A photograph of the sediment was logged and approximately 1 kg of sediment was taken for particle size analysis (PSA) analyses. A total of 57 samples were successfully collected and the data will be processed at a later stage. The data will be used to generate sediment maps for this area and also to ground-truth any seabed mapping programmes (www.infomar.ie). Figure 5.5.1.9. shows the photographs of two sediment samples collected during the FU20-21 UWTV in 2018.

Figure 5.5.1.9. Photographs of two sediment samples taken during the 2018 FU2021 UWTV survey.

CTD data.

CTD data has been collected routinely on Marine Institute UWTV surveys in recent years using a sledge mounted unit. Figure 5.5.1.10 is the bottom temperature map from 2017 Aran TV survey. These data are relatively easy to collect and is viewed as an emerging time-series which will be used for looking at interannual and longer term variability of bottom sea temperature around the coast of Ireland. The data have been used in the past to validate the temperature field in the Marine Institute operational North-east Atlantic hydrodynamic model.

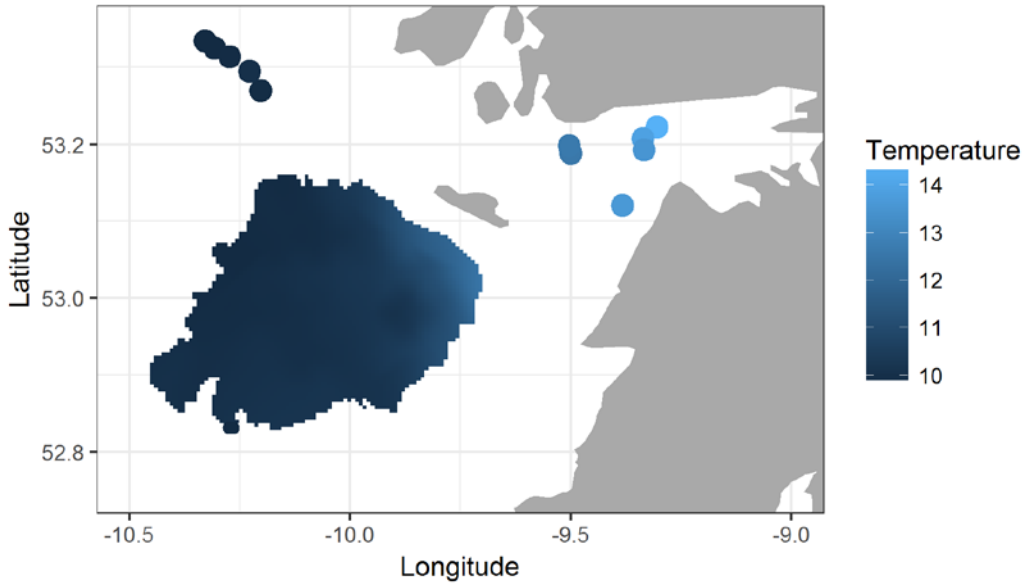


Figure 5.5.1.10. Bottom temperature as recorded during the 2017 Aran UWTV survey.

Beam trawl data

Once TV operations have been successfully completed on the Aran (FU 17) and Smalls grounds (FU 22), approximately 10 beam trawls are carried out where these fishing stations are chosen randomly. The beam trawl (3 metre beam, height 0.75 metre with a 10 mm liner mesh) is towed for 30 minutes on the seabed once ground contact is made. All *Nephrops* caught are sorted by sex and female maturity category, measured using the NEMESYS electronic caliper measuring system and weighed using a bluetooth marine scales. A length stratified subsample of *Nephrops* was taken from each haul where individual length, whole weight and maturity were recorded. The fish catch is identified to species level and sampled by weight (kgs) only. The benthic catch is identified, weighed (g) and counted. The length frequency data are useful as may detect signals of possible recruitment. Figure 5.5.1.11. presents the length frequency distributions for the Smalls where a strong cohort can be tracked in years 2006 to 2008. Benthic data are analysed and presented as a heat map and dendrogram which identifies stations which have similar compositions (Figure 5.5.1.12).

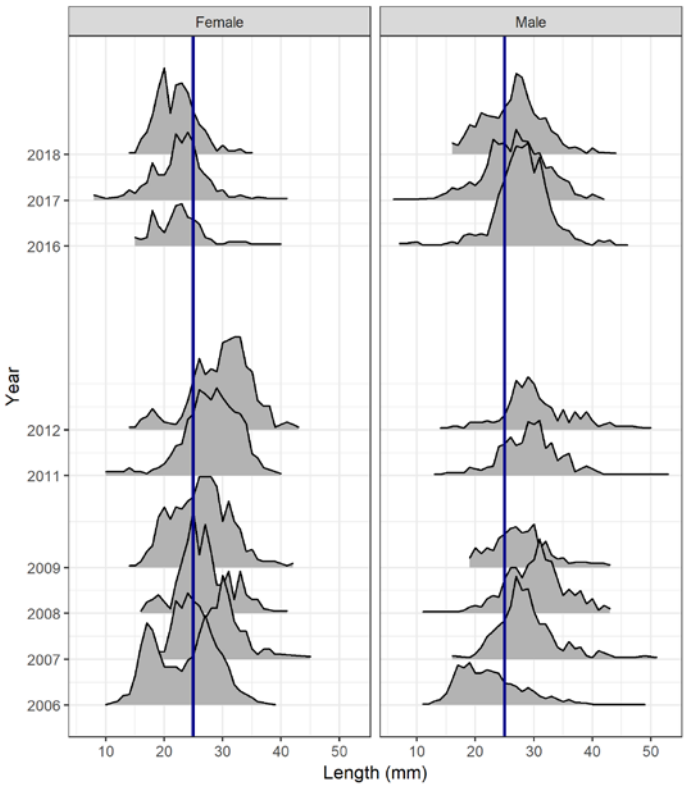


Figure 5.5.1.11. FU22 Smalls grounds: Standardized length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2018 UWTV surveys (except years 2010 and 2013 - 2015).

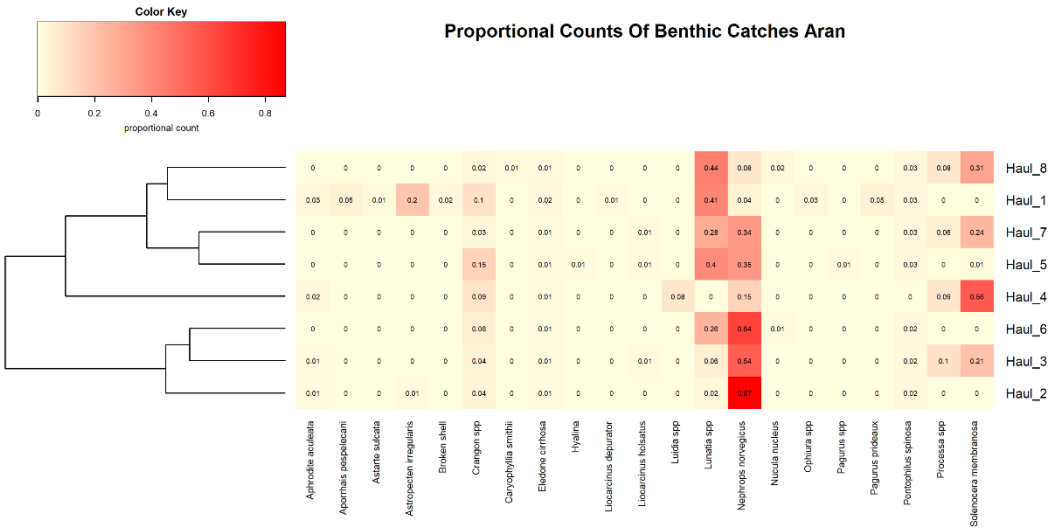


Figure 5.5.1.12. FU17 Aran grounds: 2018 Heat map of proportional counts of benthic species and dendrogram.

Other Benthic fauna distributions.

The deep-water sea-pen *Kophobelemnon stelliferum* has been observed during the UWTV survey on the Porcupine Banks (FU16) *Nephrops* ground. It is an easy species to identify from the image data due to

its specific shape and colour. Its presence/absence is mapped from the time-series to date and it is found in depths ranging from 340 to 575 metres occurring in colonies (Figure 5.5.1.13).

Monitoring the occurrence and frequency of other sea-pens observed on *Nephrops* grounds is important but depends on national resources. An OSPAR special request to record sea pens species (*Virgularia mirabilis, Funiculina quadrangularis and Pennatula phosphorea*) using a key devised to categorize the density (ICES, 2011) exists. Figure 5.5.1.14. shows the 2018 stations where *Virgularia mirabilis* (vm) and *Pennatula phosphorea* (pp) were identified and classified according to abundance key.

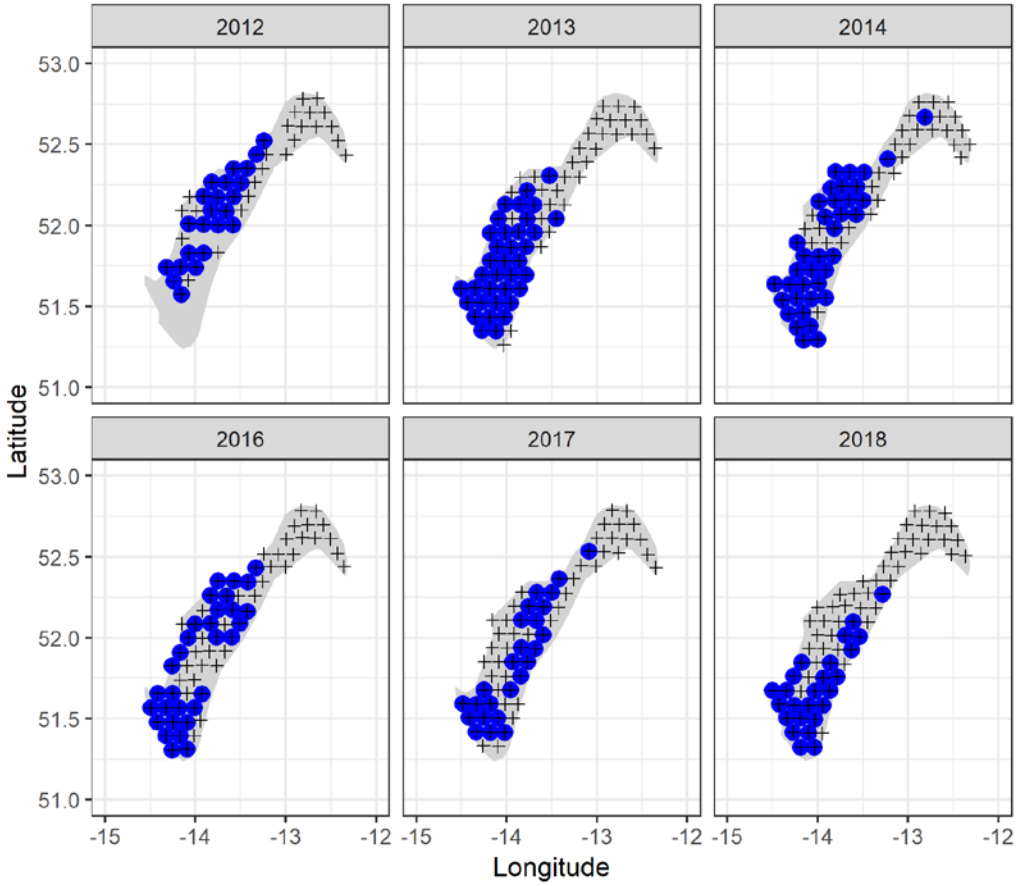


Figure 5.5.1.13. The presence/absence distribution of the deep water sea-pen species *Kophobelemnon stelliferum* observed on the video footage 2012 to 2018. Single (+) denotes no observation and blue circle denotes presence. Partial coverage in 2012. No UWTV survey in 2015 due to vessel breakdown.

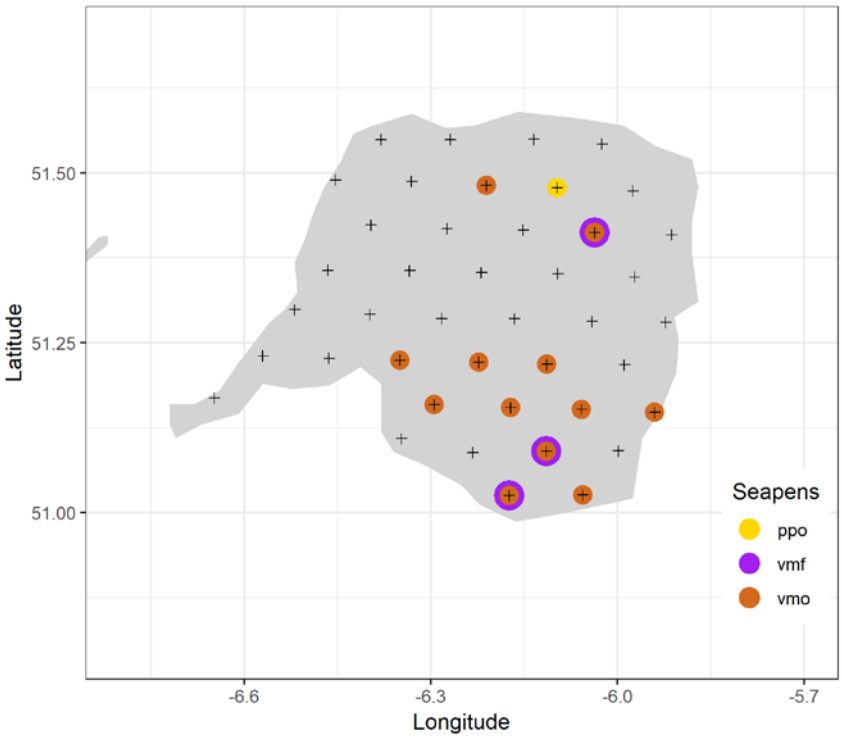


Figure 5.5.1.14. FU22 Smalls grounds: 2018 stations where *Virgularia mirabilis* (vm) and *Pennatula phosphorea* (pp) were identified and classified according to abundance key - occasional (o), frequent (f), common (c). Single (+) denotes TV stations with no sea-pen observations.

High definition camera equipment developments.

In 2018 further testing with the HD CathX Ocean Ivanov custom built camera system was carried out. The main features of camera system include: high intensity strobing light, HD video and UHD stills simultaneously and range finding laser, and also integrated geolocation metadata with each image. 27 stations were completed during the last TV survey in August on the Smalls *Nephrops* grounds at 75 degree angle and at various frame save rates : 15 frames per second (fps) , 12 fps and 10 fps at Ultra HD.

Once the standard footage was obtained at a station the system was switched over to HD capture mode. The footage covered a range of densities and visual clarity also. A standard operating protocol for users in the new software was developed on-board. Next stage is to review UHD stills and compare counts with those data from the standard camera. Also to progress the data work flow onboard from harvesting metadata from the images through to data storage and visualization. Further work will continue in mosaicking the UHD stills which should result in significantly better quality images than mosaicking HD video alone. These high quality mosaics can be used to annotate and measure burrow systems and other features of interest. In the future it is envisaged to use feature detection algorithms and deep learning to automatically identify *Nephrops* burrow systems and other features of interest. Figure 5.5.1.15 shows high definition still images from trials with this equipment and it shows clearly the high quality of the images.

Figure 5.5.1.15. High definition still images from 2018 UWTV survey HD camera system trials. Camera angle 75 degrees, range laser (red dot) and on screen display output (T=Time, R= range laser, N = positional data). The blurred particles in the lower image is marine sediment that is "frozen" when the image is captured. © Marine Institute Ireland.

Conclusions/recommendations

- Continue to develop the use of high definition camera and still images with the objective to mosaic images so that deep learning algorithms can be developed in future to identify features.
- Promoting and facilitating when possible on UWTV surveys, staff exchange from national laboratories.

Promoting and facilitating when possible on UWTV surveys, staff exchange from other institutes who may use the UWTV survey data.

5.1.2 UK Northern Ireland

(Annika Clements)

This was the 16th annual survey in a time-series of UWTV surveys in the Irish Sea (ICES Division VIIa) carried out jointly by the Agri-Food and Biosciences Institute (AFBI), Northern Ireland (UK), the Marine Institute, Ireland, and Cefas, UK. The survey took place on RV *Corystes* between 30th July and 9th August 2018. The survey covered the western Irish Sea (FU15) (reported in this section) and the eastern Irish Sea (FU14) (reported under UK-England).

The specific objectives of the survey are listed below:

1. To complete a randomized fixed isometric survey grid of 100 UWTV with 4.5 nautical mile (nM) spaced stations on the western Irish Sea *Nephrops* ground (FU15);
2. To obtain 2018 quality assured estimates of *Nephrops* burrow distribution and abundance for FU15. These will be compared with those collected previously;
3. To collect ancillary information from the UWTV footage at each station such as the occurrence of sea-pens, other macro benthos and fish species, and trawl marks on the seabed;
4. Technology, staff and protocol transfer between AFBI, the Marine Institute and Cefas.
5. To implement the application of Lin's concordance correlation coefficient (CCC) with a threshold of 0.5 agreement between recounts per station to determine which stations required third (or further) recounts to ensure agreement between counts.

FU 15 Western Irish Sea

From 2003 to 2018 a randomized fixed square grid for the western Irish Sea (FU15) *Nephrops* ground has been used. An adaptive approach is taken whereby stations are continued past the known perimeter of the ground until the burrow densities are zero or very close to zero. The initial ground perimeter has been established using a combination of integrated logbook-VMS data (using the methods described in Gerritsen and Lordan, 2011), British Geological Survey (BGS) and other sediment maps, and previously collected UWTV data. The same ground boundaries have been used throughout the time-series. The grid spacing from 2003 to 2011 was 3.5 nautical miles (nM). Following a review (Doyle *et al.,* 2013) the grid design was changed from a 3.5 nM to 4.5 nM in 2012. In 2013, the grid spacing was increased further to a 5.0 nM isometric grid, whereas a 4.5 nM isometric grid was used again in 2014 - 2018 to ensure all edge of ground areas were represented adequately.

The main motivation to increase the grid spacing was to achieve full spatial coverage of FU15 while giving the option to reallocate ship time to increase coverage in other Functional Units (FU16, FU20–21 and FU19); also in line with SGNEPS recommendations (ICES, 2012). Reducing the number of stations was not expected to significantly affect the accuracy of the survey estimate, supported by the apparent strong spatial autocorrelation in density across the area (Doyle *et al.* (2013)). The precision (measured by the coefficient of variation) indeed has not been significantly reduced in 2012 – 2018 by comparison to earlier years, with a CV of 3% which was in line with previous estimates (varying between 2 – 4%), all of which are well below the SGNEPS 2012 recommendation of 20% (ICES, 2012.

The 2018 design consisted of a randomized isometric grid of 100 stations at 4.5 nautical mile intervals out over the full known extent the stock (Figure 5.1.2.1). At each station, the UWTV sledge equipped

with standard definition camera with a known field of view (0.75 m) was deployed and once stable on the seabed a 10-minute tow was recorded onto DVD. Vessel position (dGPS) and position of sledge (using an USBL) were recorded every 1 to 2 seconds. All stations were successfully surveyed with 14 re-do stations due to visibility issues on first attempts, or equipment failure. Nine stations were also completed opportunistically in Belfast Lough over grounds identified as *Nephrops* ground from the 2015 survey; together with data gathered in the lough over the previous four years the extent of this ground will be established to ensure sampling design is appropriate.

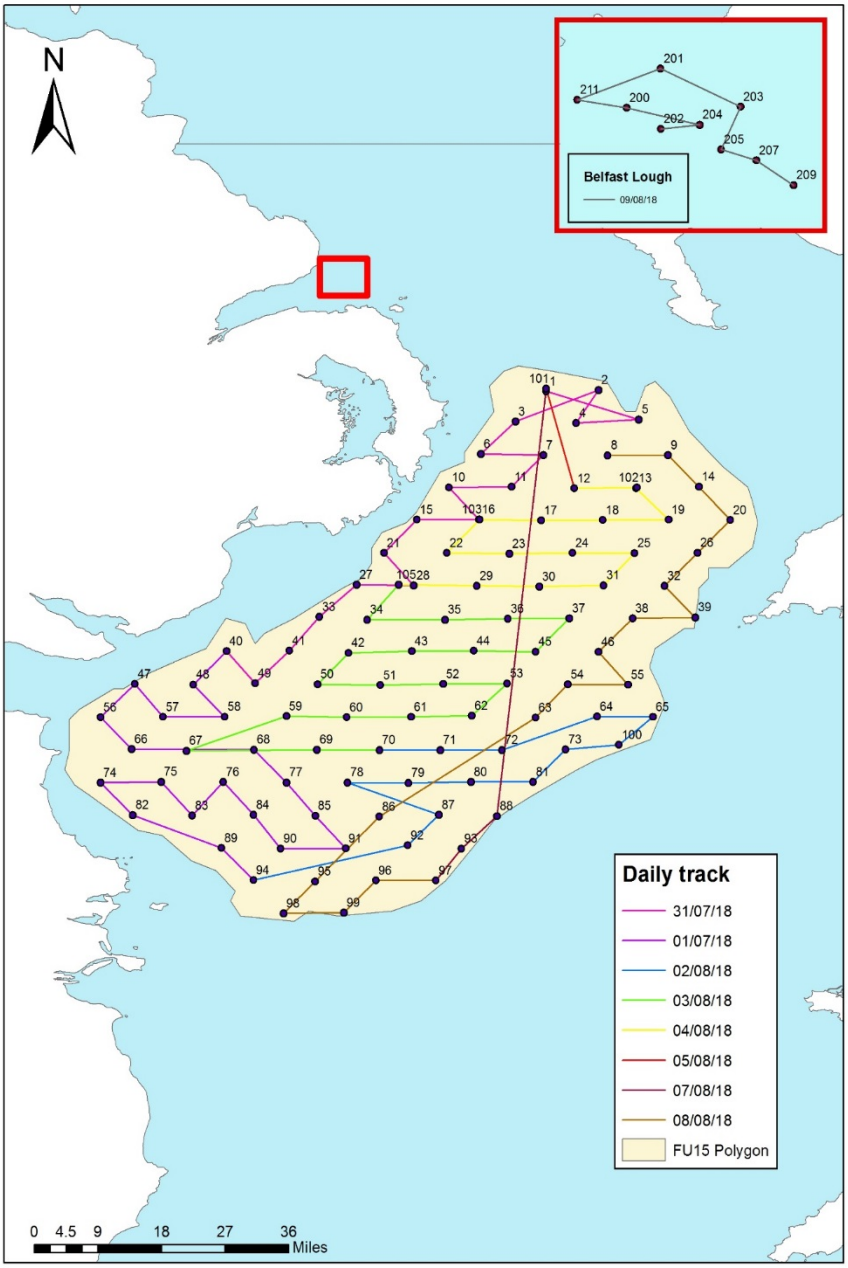


Figure 5.1.2.1: FU15 western Irish Sea grounds (including Belfast Lough): Stations completed on the 2018 UWTV Survey.

The navigational data were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b). In 2018, due to USBL failure, ship navigational data were used to calculate distance over ground for 100% of stations. Improvements had been made to the UWTV database and related R scripts for 2018 to facilitate survey progress monitoring and data management. An updated SQL database is now in use at AFBI to store all *Nephrops* UWTV data.

Lin's CCC was applied during the survey to all recounts to identify those stations which required a third independent count, with a threshold of 0.5 used. Third recounts were checked again using Lin's CCC and if the statistic remained below the threshold of 0.5, and fourth independent count was completed. If yet again the statistic remained below the threshold of 0.5, a consensus count was completed by the four counters who had previously counted the footage. 35% of stations required a third count, Following third counts over 82% stations successfully met these threshold, however 7 stations did not pass after having 4 counts by independent staff and a consensus count was carried out for each of these stations. Certain areas within the ground are problematic from a burrow detection and identification perspective due to the presence of multiple burrowing species: training to improve discrimination in such areas will continue to be a focus in future surveys.

Within the western Irish Sea, the average burrow density (adjusted to account for bias factors) was 0.82 burrows/m^2. This is a 9% decrease from the 2017 figure of 0.90 burrows/m^2 (see Figure 5.1.2.2). The summary statistics from the geostatistical analysis show in 2018 a final abundance estimate (adjusted to account for bias factors) of 4.9 billion burrows, which is close to that estimated in 2011 (see Figure 5.1.2.3). The overall burrow abundance trend is fairly stable although the abundance did decline between 2007 and 2008, and between 2012 and 2015. 2016 and 2017 showed an increase in abundance prior to the decline in 2018. The survey precision as measured by the coefficient of variation for 2018 was 3% indicating a very precise survey in line with CVs observed previously (see Table 5.1.2.1). A comparison of geostatistical analysis using "R-Geostats" and the usual "Surfer" method was made, with a consistent trend agreement observed between the Surfer based estimate and R-Geostats, however, with a positive bias (mean = .23).

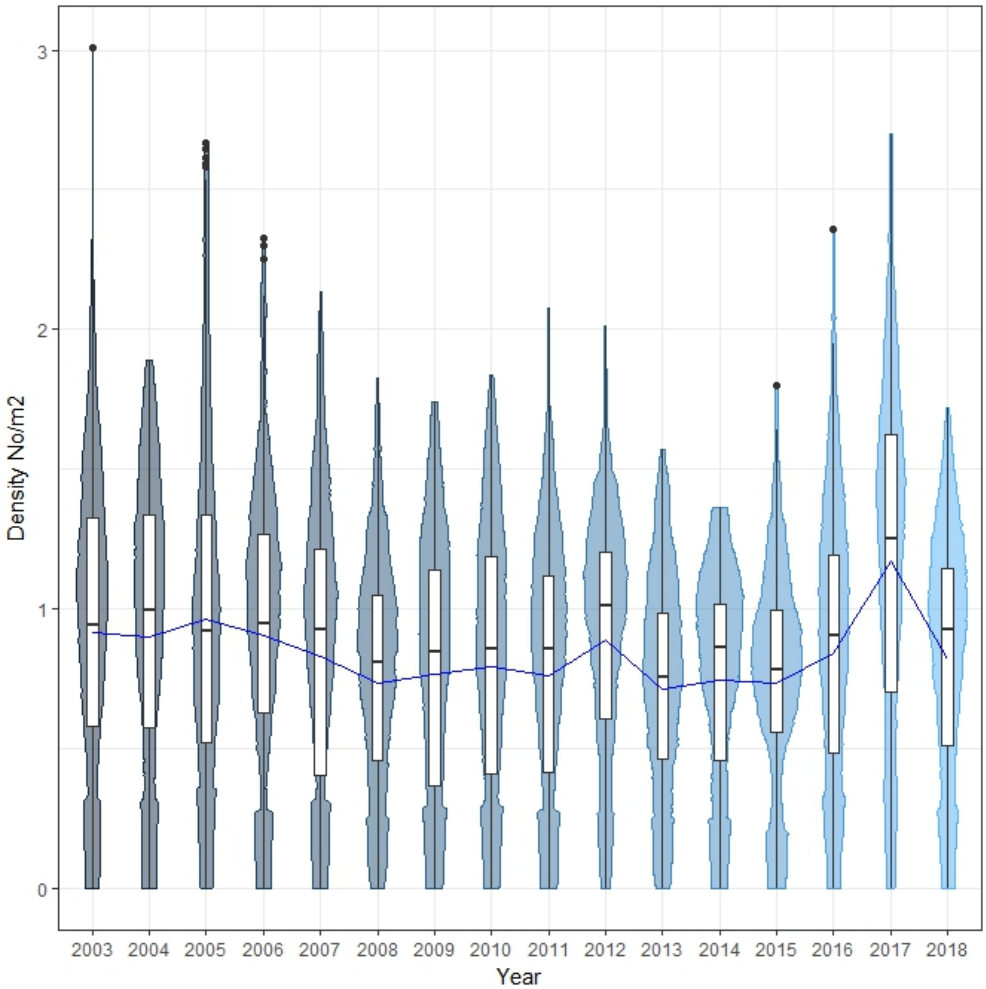


Figure 5.1.2.2: FU15 western Irish Sea grounds: Violin plot of burrow density distributions by year from 2003-2018.

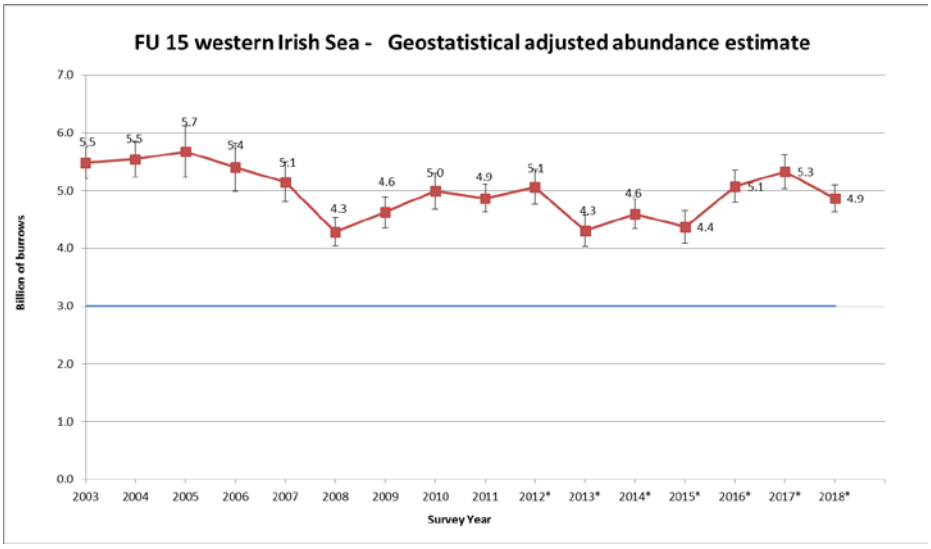


Figure 5.1.2.3: FU15 western Irish Sea grounds: Time-series of geostatistical adjusted abundance estimates (in billions of burrows) from 2003 -2018. Error bars correspond to the 95% confidence intervals calculated in EVA. Blue horizontal line is $B_{trigger}$ of 3.0 billion burrows.

Table 5.1.2.1: FU15 western Irish Sea ground: Overview of geostatistical results from 2003-2018.

Year	Number of stations	Mean Density adjusted (burrows./m²)	Domain Area (km²)	Geo-statistical abundance estimate adjusted (billion burrows)	R-GeoStats Estimate	CV on Burrow estimate
2003	160	0.99	5295	5.5	5.8	3%
2004	147	1.00	5310	5.5	5.8	3%
2005	141	1.02	5281	5.7	6.1	4%
2006	138	0.97	5194	5.4	5.9	4%
2007	148	0.93	5285	5.1	5.4	3%
2008	141	0.77	5287	4.3	4.5	3%
2009	142	0.83	5267	4.6	4.9	3%
2010	149	0.90	5307	5.0	5.1	3%
2011	156	0.88	5289	4.9	5.2	2%
*2012	99	0.91	5291	5.1	5.5	3%
*2013	80	0.78	5278	4.3	4.5	3%
*2014	99	0.83	5272	4.6	4.6	3%
*2015	100	0.79	5279	4.4	4.4	3%
*2016	100	0.84	5260	5.1	5.2	3%
*2017	101	0.90	5304	5.3	5.4	3%
*2018	100	0.85	5791	4.9	4.9	3%

*reduced isometric survey grid

The geostatistical analysis used to estimate total abundance over the FU15 ground result in density contours that correspond well to the observed data. The interpolated (krigged) density surfaces show a relatively dynamic situation over the survey series (2003-2018) – see Figures 5.1.2.4-5.1.2.6 below. Some parts of the ground have consistently higher or lower densities, such as to the southwest of the ground, near the northern-most extent of the ground, with a further 'hot spot' to the east of the ground (south-west of the Isle of Man). In most areas densities drop to zero or near zero as the ground boundary is approached, with the exception in 2016 - 2018 (and to a lesser extent in 2014) across the widest part of the ground at the western and eastern (immediately SW of Isle of Man) boundaries. There tends to be a lower density towards the centre of the ground. The 2018 spatial pattern is most similar to that in 2012, but with slightly lower densities observed towards the southern end of the ground. The high density areas observed in the FU15 in the past had almost disappeared in recent years, however 2016 and 2017 has exhibited some stations with an average burrow density of greater than 2 systems/m2; but in 2018 there were no densities this high observed, with the densities similar to those observed in 2009.

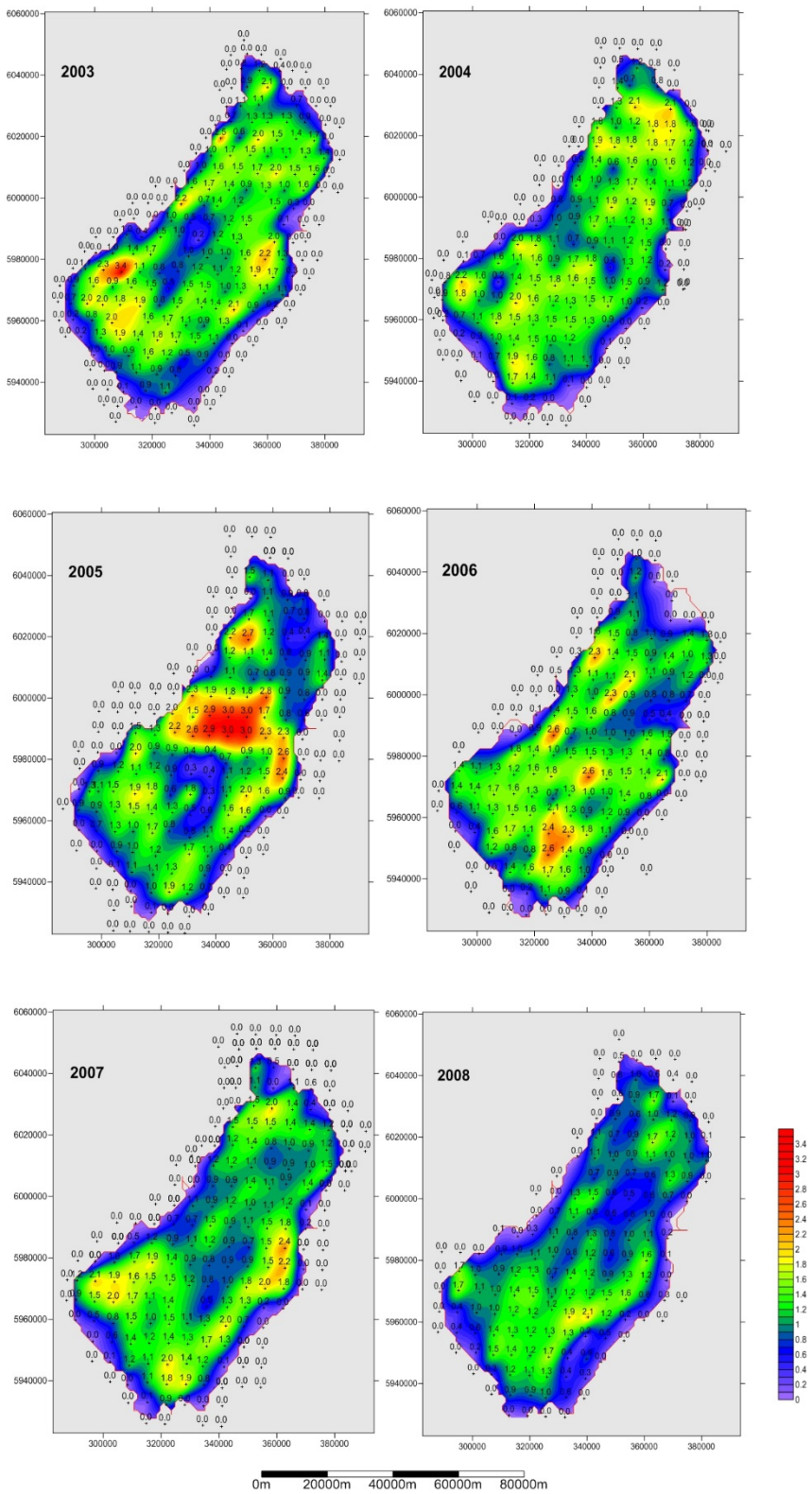


Figure 5.1.2.4: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2003 -2008.

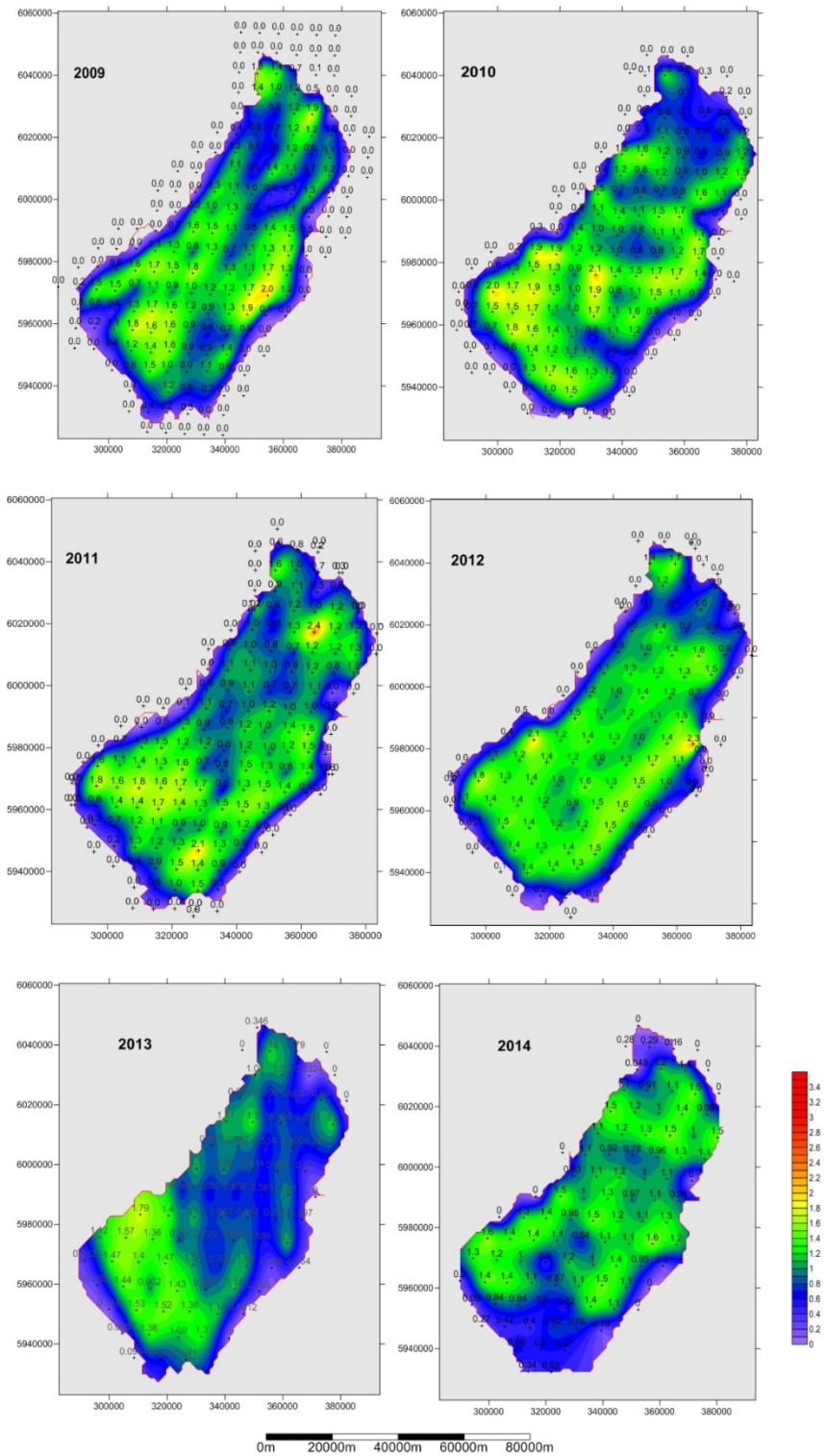


Figure 5.1.2.5: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2009 -2014.

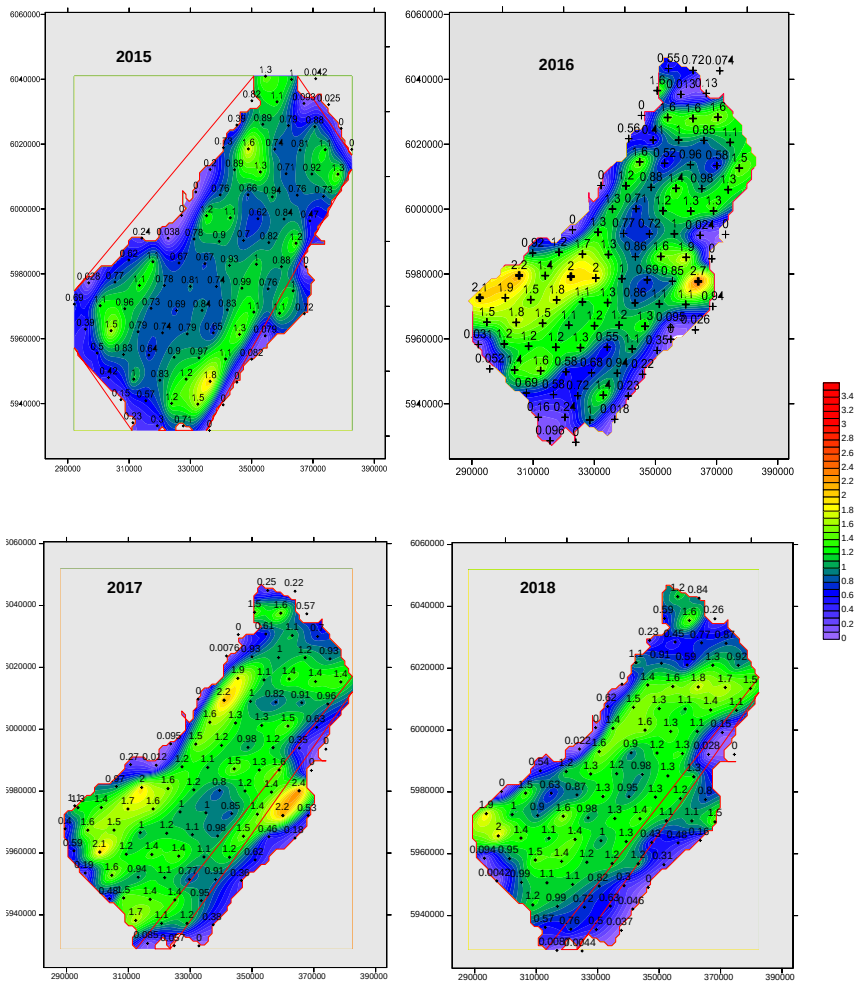


Figure 5.1.2.6: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2015 -2018.

From the UWTV footage, notes were also recorded on the occurrence of trawl marks, fish species and other species. Semi-quantitative assessment of sea-pen species were also recorded according to OSPAR Special Request (ICES, 2011). Sea-pens were identified from the video footage as *Virgularia mirabilis* with one record of *Pennatula phosphorea* (which requires verification); 20% of the 2018 survey stations had *V. mirabilis* present (very similar pattern to 2017) – see Figure 5.1.2.7. Trawl marks were noted at 26% of the stations surveyed, 10% less than those noted in 2018 (Figure 5.1.2.8).

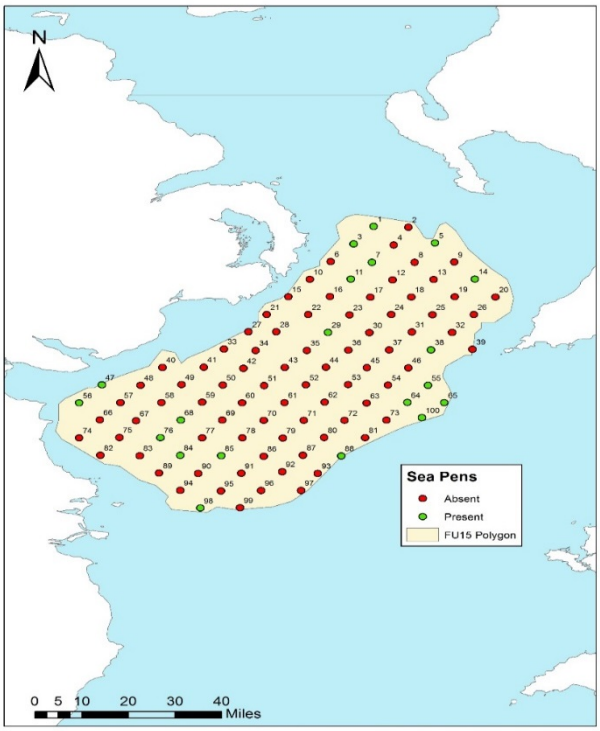


Figure 5.1.2.7: FU15 western Irish Sea ground stations where the seapen *Virgularia mirabilis* was identified during 2018.

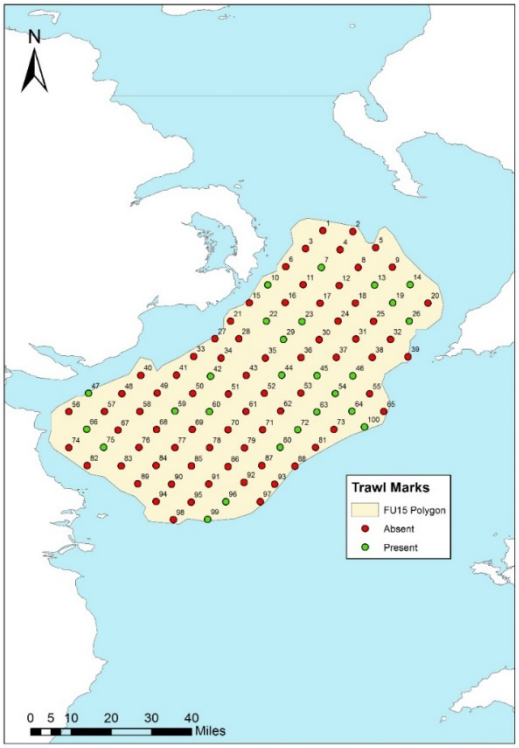


Figure 5.1.2.8: FU15 western Irish Sea ground stations where trawl marks were observed during 2018.

Within Belfast Lough, average burrow density was 0.21 burrows/m^2 (adjusted to account for bias factors using FU15 correction factor) and sea-pens (*V. mirabilis*) were present in one of the stations. Burrow systems appeared notably larger in size than those viewed over the majority of the western Irish Sea.

A trawl survey (Annex 8.1 method statement/Standard Operating Procedure) was also completed from 20th – 23rd August, with 24 trawl stations across FU15 sampled by *Nephrops* trawl and 22 stations sampled by a 2m beam trawl: 14,152 *Nephrops* were measured to generate length frequencies for males and females and establish the sex ratio.

A drop frame UWTV survey for *Nephrops* abundance assessment in Strangford Lough was commenced in 2017 with a repeat completed in 2018. Further work is ongoing to define the potential *Nephrops* ground using existing multibeam sonar data and grab sampling, and other available data (spyball video, creel data). As the Lough is protected (as a Marine Conservation Zone and Special Area of Conservation) with a non-disturbance zone covering part of the subtidal area, a drop frame was necessary. 35 stations were surveyed in 2018. Counting burrow systems from a drop frame presents different challenges due to the angle of view and lighting, and some further refinement of the equipment set up may be needed to facilitate burrow identification.

Future developments:

The FU15 survey still uses a standard definition/analogue camera, with a non-load-bearing cable which requires cable-tying to the winch wire for each deployment. Procurement is underway to update the camera system availing of newer high definition (HD) technology, and replace the cable with a load-bearing cable and new winch. The new system is hoped to allow future use of stills mosaics and image classification/tagging.

Conclusions/recommendations:

There is a need for continued collaboration between the three national laboratories involved in this survey (Agri-Food and Biosciences Institute (AFBI), Northern Ireland (UK), the Marine Institute, Ireland, and Cefas, UK)

5.1.3 UK Scotland

(Katie Boyle, Adrian Weetman)

Marine Scotland Science (MSS) based in Aberdeen, Scotland, UK, carried out three underwater camera based TV surveys (UWTV) in Scottish waters in 2018. Each survey was completed on one of MSS' own research vessels and continues work which first began in 1992. The data collected adds to the growing dataset in both number of deployments but also the variety of grounds visited as seen in Figure 5.1.3.1 below.

The equipment used in 2018 remained unchanged from previous years with a Kongsberg 14-366 analogue video camera; four SeaLED lights; an odometer to calculate the distance travelled; an altimeter to record the position of the camera in relation to the seabed (which is used to calculate the field of view) and a mini van Veen sediment sampler. Each of the devices was used on the TV sledge, with the drop

frame only requiring the Kongsberg camera and four SeaLED's. Only the sledge was used to carry out *Nephrops* abundance work, and all three surveys fully met their planned objectives.

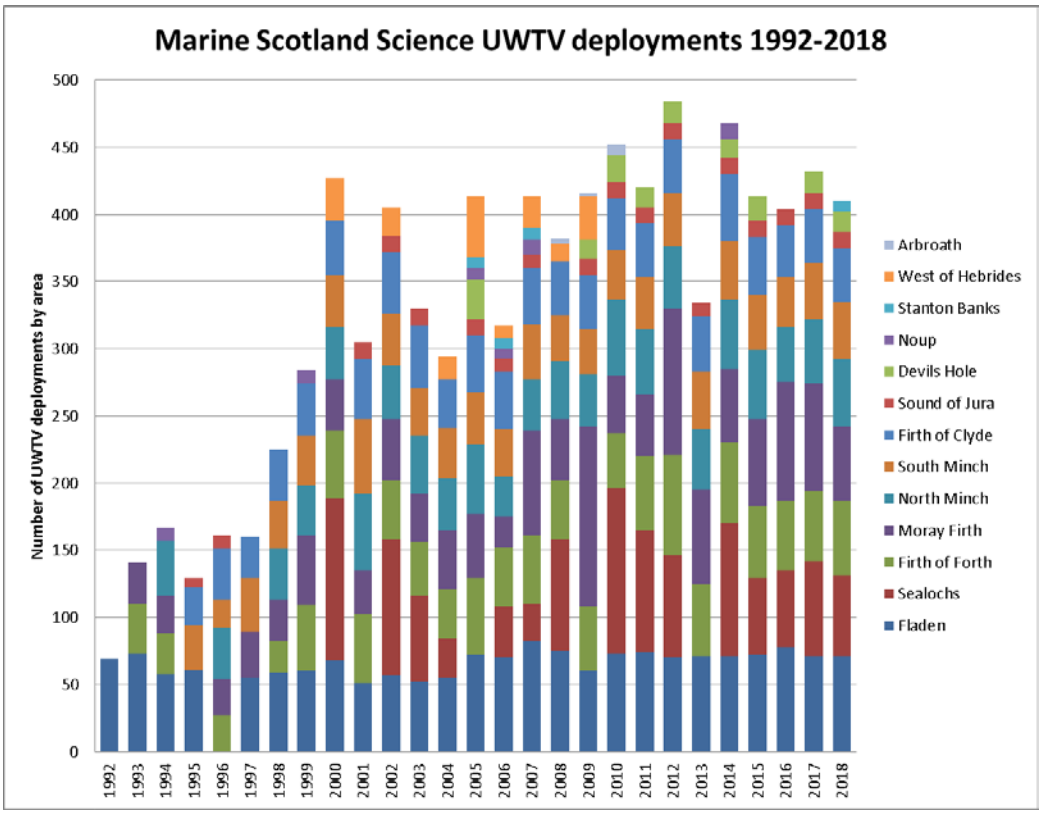


Figure 5.1.3.1. Time-series of UWTV sledge and drop frame deployments by MSS for all areas surveyed, in relation to *Nephrops* burrow abundance, habitat mapping and comparative trials.

Alba-na-Mara, 6 – 22 January 2018

The 17 day, annual West coast winter survey was completed aboard the 27m long Marine Research Vessel (MRV) Alba-na-Mara. This non-Data Collection Framework funded survey provides support for the annual, summer surveys carried out by MSS which gather data directly for management advice through the ICES assessment process.

Following on from the survey in January 2016 (cruise 0116A), this survey had several objectives with the priority being to carry out investigative video camera work on *Nephrops* grounds to the northwest of Jura and the area between the Isle of Skye and the mainland (in the South Minch, FU12). This was achieved using the underwater television sledge (UWTV) at randomly selected locations within an area where previous work and anecdotal information had implied there was muddy sediment suitable for *Nephrops* to inhabit. The sledge deployments and data gathering, analysis and processing were all conducted to the standards as agreed by WGNEPS, and with good visibility throughout and calm sea conditions, valuable data were obtained.

During a period of poor weather sledge and drop frame comparative trials were carried out in Loch Linnhe (South Minch). This work adds to the dataset started in 2012, and aims to provide a correlation

between abundance values obtained using the UWTV sledge and the drop frame by surveying the same ground using alternating methods in a predetermined manner, ensuring the tow paths of both devices intersect.

All video footage obtained during this survey was reviewed as per WGNEPS guidelines, although further statistical analysis is required to provide any conclusive outcomes.

Sediment samples, to be used in particle size analysis (PSA), were gathered at each station where possible using either the sledge mounted mini van Veen or ship launched Day grab. Analysis on the material will be carried out using MSS facilities and will help refine existing sediment distribution charts.

Table 5.1.3.1. Summary of UWTV activities carried out during the MRV Alba-na-Mara cruise in January 2018 within the South Minch (FU12).

Location	Number of UWTV sledge deployments	Number of sediment samples	Number of comparative tows with UWTV sledge	Number of comparative tows with UWTV drop frame
North West Jura	17	16	0	0
Sound of Raasay	17	17	0	0
Loch Linnhe	0	15	17	9
Total	34	48	17	9

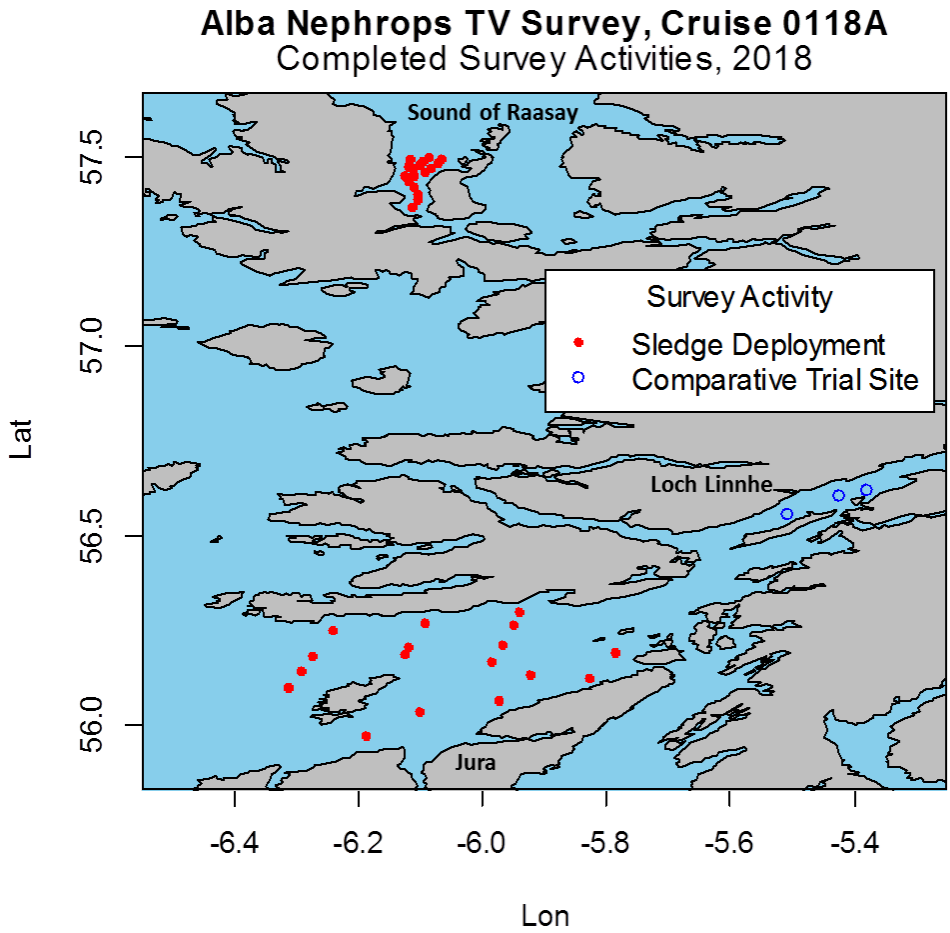


Figure 5.1.3.2. Map illustrating the location of the various UWTV activities carried out during the MRV Alba-na-Mara cruise in January 2018 within the South Minch (FU12).

Scotia, 3 – 25 June 2018

The 2018 UWTV survey aboard MRV Scotia involved eight members of staff, including a trainee engineer. In addition to the standard objectives of surveying the *Nephrops* grounds at Fladen, in the North and South Minches, the Clyde and off Jura, this survey was charged with deploying an Acoustic Doppler Current Profiler (ADCP) at Fladen, and to recover and then redeploy seven moorings on the west coast. To facilitate this extra work, the trip was extended to 23 days, and despite losing a significant amount of time due to significant unforeseen circumstances, poor weather and considerable equipment issues, all the objectives were met. As required a pre-survey training session was held with further advice provided throughout the trip. All video footage was reviewed in accordance with WGNEPS guidance, with quality control being carried out on all data using Lin's concordance correlation coefficient (Lin's CCC), with third counts applied where thresholds were not met (see Table 2 below). Variable weather conditions and poor subsurface visibility were experienced throughout the trip, and this was reflected in the QC outputs.

A reduced number of trawls were completed on this survey due to time factors, but catches were worked up for length frequency distribution, sex ratio, weights, morphometrics and maturity data as required. Any marine litter appearing in the catch was recorded and disposed of as per OSPAR guidance. Sediment samples for PSA were obtained at 92% of the TV stations using the sledge mounted mini van Veen at all but two of the sites.

The seven moorings which required visiting on the west coast formed part of the long term COMPASS project which aims to identify areas around Scotland in high use by cetaceans, by attaching devices to moorings to both record the sounds of passing fauna and count the number of vocal interactions. The location and favourable weather conditions of one COMPASS mooring allowed the survey to conduct UWTV work on the *Nephrops* grounds at Stanton Bank for the first time since 2002.

Additional work also conducted during this survey included:

- In conjunction with the Marine Institute, providing biological samples from a high density area within the Clyde for the National University of Ireland Galway, to be used in a PhD to study the effect of density on *Nephrops* maturity.
- Trial an Aquatic 2 temperature logger on the sledge, which produced promising but limited results.
- Following on from the work carried out in 2017, further reviewing of historical footage was completed while at sea. This involved an additional reviewer and footage from 2012 which had not previously been used. Further statistical analysis is required to allow any precise conclusions to be made.
- Due to the equipment and environmental changes that had taken place since the original reference set of training videos was created in 2009, it was recognized that there was a requirement to update the existing reference footage. New reference sets were created for three areas (North Minch (FU 11), South Minch (FU 12) and Fladen (FU 7) using 2018 footage, with the North Minch data being assessed during WKNEPS (October 2018). Reference sets for the remaining three main grounds (Firth of Forth (FU 8), Moray Firth (FU9) and Clyde (FU 13) will be produced by April 2019.

Table 5.1.3.2. Summary of *Nephrops* burrow abundance related activities carried out within the seven survey areas during the MRV Scotia cruise in June 2018. Survey design: RS – S, random stratified based on sediment; RS – E, random stratified based on VMS effort; Fixed, survey stations are fixed due to the challenging topography.

Area	Number of TV sledge deployments	Number of fishing trawls	Number of sediment samples	Linn's CCC threshold	Lin's CCC pass rate	Survey design type
Fladen	71	0	69	0.7	76%	RS -S
North Minch	50	0	44	0.5	86%	RS - E
South Minch	43	2	36	0.5	47%	RS -S

Clyde	40	2	39	0.5	60%	RS -S
Stanton Bank	8	0	7	0.5	100%	Fixed
Jura	12	0	12	0.5	67%	RS -S
Devils Hole	15	1	13	0.5	80%	Fixed
Totals	239	5	220	NA	NA	NA

On completing the survey, all footage having been reviewed and passed the standards required for assessments purposes, and all count, sediment, observations of other fauna (e.g. sea pens, fish, crustaceans, etc.), haul, biological and station data had been entered into the required format for uploading into the bespoke MSS database on returning to shore.

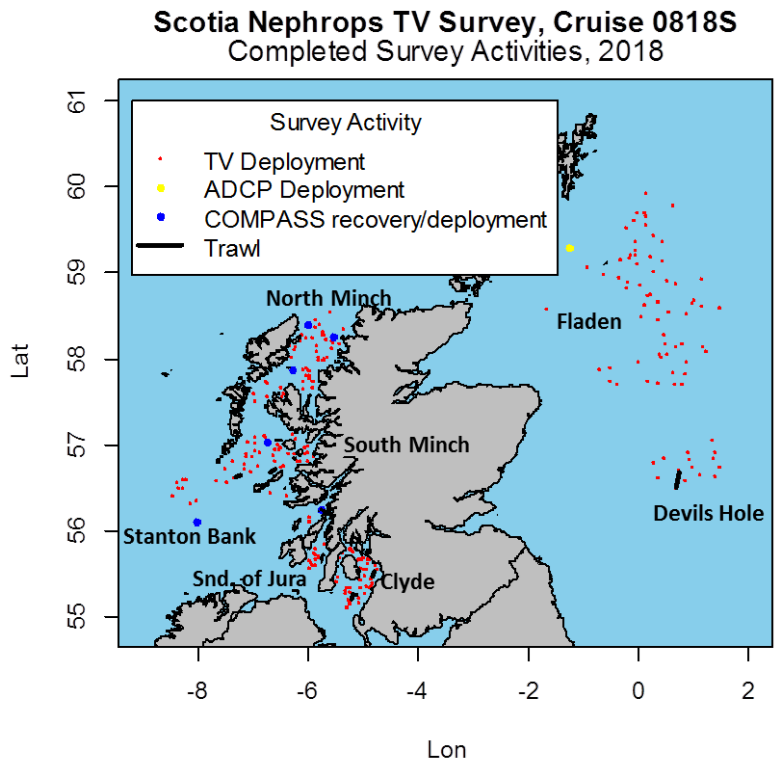


Figure 5.1.3.3. Map illustrating the location of the various UWTV activities, ACDP deployments and COMPASS mooring recoveries that were conducted within the seven survey areas during the MRV Scotia cruise in June 2018.

Alba-na-Mara, 25 August – 10 September 2018

The annual 17 day UWTV survey to the Firth of Forth (FU8) and Moray Firth (FU9) was completed from 25th August to 10th September aboard MRV Alba. This survey complemented the work carried out in June by MRV Scotia and ensured all seven of the main *Nephrops* fishing grounds around Scotland had been surveyed by the internationally accepted UWTV method and to the standards set out by WGNEPS.

In methodology, process and outcomes this survey mirrored the MRV Scotia survey, allowing the results to be directly comparable, and fully met all that was required to provide data for the stock assessment process.

Other than sailing a day later than planned due to poor weather no further issues were encountered during the survey. The UWTV sledge was used throughout this survey. The vessel initially surveyed the Moray Firth, followed by the Firth of Forth, and a combination of three staff were required to lead the survey at different times for a variety of reasons, with staff levels varying between two or three at any one time. On occasion, stations had to be relocated due to ship wrecks (but still remaining within the same sediment type and spatial zone) and the survey concluded by achieving its objectives by surveying the required number of stations and acquiring sufficient data for analysis necessary to carry out assessments in these two areas, to generate stock management advice.

All footage was gathered and reviewed in line with WGNEPS guidance, with a high pass rate when Lin's CCC was applied (see Table 3 below). Third counts were completed at sea when possible with some footage being reviewed for a third time onshore due to the limited number of staff on board.

The *Nephrops* component of the three trawls was sampled for length frequency distribution, sex ratio, weights, morphometrics and maturity data. A further sample of *Nephrops* were collected for NUI, this time from an area within the Moray Firth with a known low density of *Nephrops*, to compliment the sample obtained on MRV Scotia from a high density ground. All marine litter appearing in the catch was recorded and disposed of as per OSPAR guidance.

Sediment samples for PSA were obtained at all but one site. However due to the varying nature of the seabed, only 66% were obtained using the sledge mounted mini van Veen grab, with the Day grab retrieving the remaining samples.

On completing the survey, all footage having been reviewed and passed the standards required for assessments purposes, and all count, sediment, observations of other fauna (e.g. sea pens, fish, crustaceans, etc.), haul, biological and station data had been entered into the required format for uploading into the bespoke MSS database on returning to shore.

Table 5.1.3.3. Summary of *Nephrops* burrow abundance related activities, carried out the MRV Alba-na-Mara cruise during August/September 2018 within the Firth of Forth (FU 8) and the Moray Firth (FU 9).Survey design: RS – S, random stratified based on sediment.

Area	Number of TV sledge deployments	Number of fishing trawls	Number of sediment samples	Linn's CCC threshold	Percentage pass rate	Survey design type
Moray Firth	55	1	54	0.5	82%	RS - S
Firth of Forth	56	2	56	0.5	89%	RS - S
Totals	111	3	110	NA	NA	NA

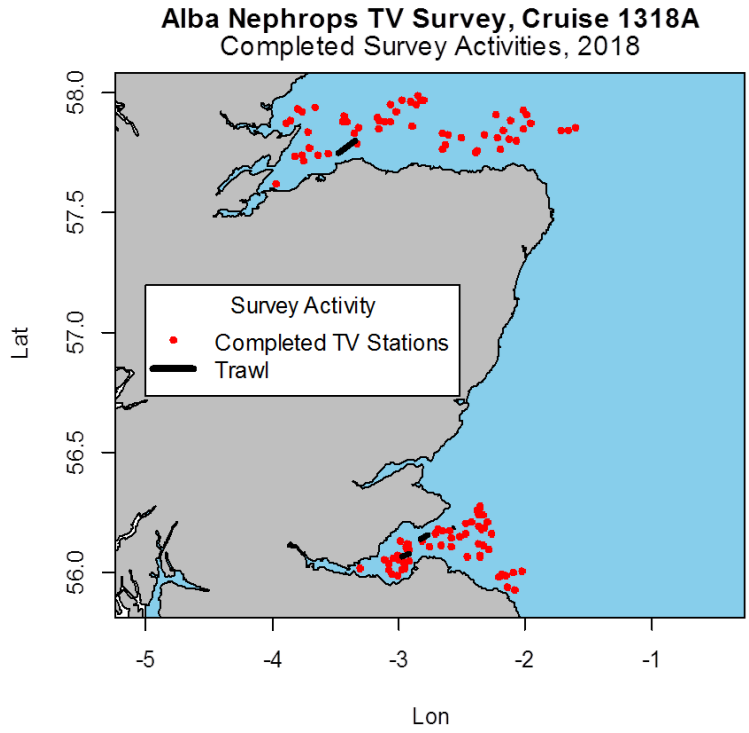


Figure 5.1.3.4. Map illustrating the location of the various UWTV activities carried out during the MRV Alba-na-Mara cruise during August/September 2018 within the Firth of Forth (FU 8) and the Moray Firth (FU 9).

Conclusions/recommendations:

- To further encourage and promote national and international staff exchange.
- To trial a stand-alone high definition video camera in parallel with the standard, coaxial analogue camera (January 2019).
- To continue to promote the UWTV surveys to being open to alternative, but appropriate and collaborative, use of staff experience and ship's time to improve cost and time efficiencies, widen the survey remit and increase staffs' skill base.
- To produce reference sets for the Firth of Forth (FU 8), the Moray Firth (FU 9) and the Clyde (FU 13).

5.1.4 UK England

(Robin Masefield)

UK England is currently responsible for the assessment of 3 different FU, although only two have regular UWTV surveys (FU6 and FU14), being FU5 classified as data-limited stock.

FU5: Botney Gut - Silver Pit

Due to funding constraints Cefas (UK) is no longer covering this ground, although the possibility of having a collaborative survey in future is being discussed with the Netherlands. More information regarding future options to reinstate this survey will be discussed in the near future and this information will be passed on to the WGNEPS.

FU6: Farn Deeps

The Farn Deeps survey design is based on a randomized fixed grid and includes a total of 110 stations (Fig 5.1.4.1). The initial ground perimeter has been delimited by the combination of VMS data and BGS sediment maps. An additional 16 stations were completed during the past three year's surveys, not forming part of the standard survey.

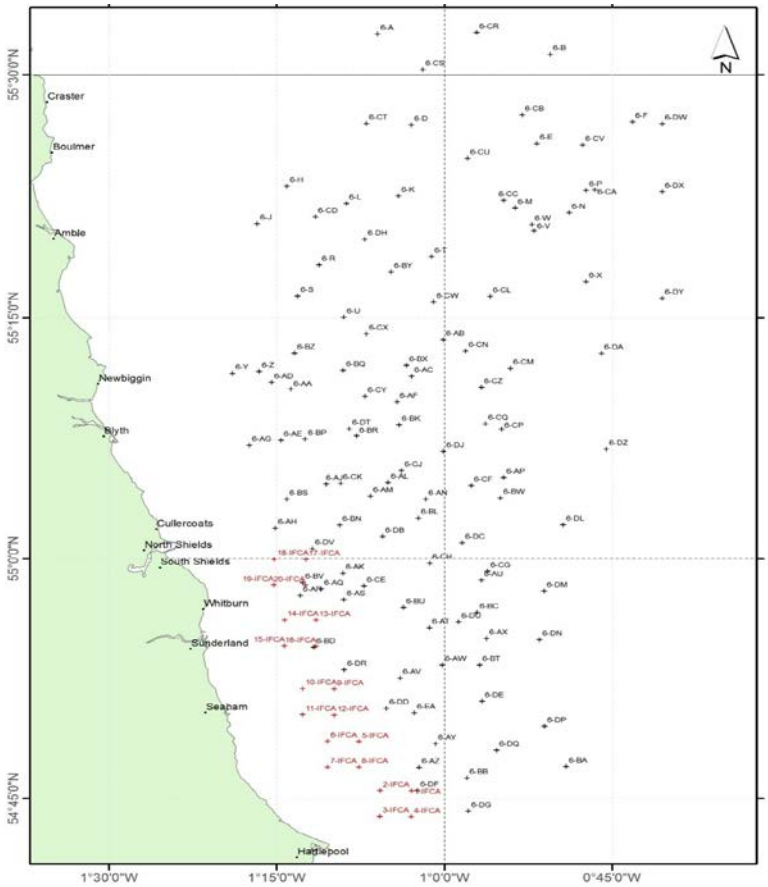


Figure 5.1.4.1 – Map showing the location of the surveyed area in the Function Unit 6 area (110 stations) and the 15 additional NEIFCA stations.

These additional stations form part of a UWTV survey planned to take place by NEIFCA (Northeast Inshore Fisheries and Conservation Authority) in autumn of each year on grounds within 6 nm from the coast. The stations were included to allow comparisons of the burrow densities before and after the peak moulting period. To date NEIFCA have been unable to carry out the survey so analysis hasn't taken place. These stations will be removed for the 2019 survey.

At each station a sledge mounted TV camera was deployed and a clear 10 minute tow was recorded to MP4 video files, recorded directly to two separate drives to provide a backup. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 10 seconds.

Survey gear used for the FU6 UWTV survey has remained the same for the last three years (2016-2018), using OLED monitors (Sony 25-inch professional PVM-A250) a Kongsberg camera (720p, 24fps), green fan lasers (rated to 3000m, 520nm wavelength), 6 LED lights (20w) and on-board control system. The Rochester armoured cable was used as in previous years, although only the coax components were required for delivery of power and control of all peripherals. It is anticipated that we will go over to fibre optic umbilical for the 2019 survey. The swept-area is calculated using the ships positioning rather than the sledge position (USBL) for FU6.

The work was all undertaken according to the standard protocols which include pre-survey training and standardization of counter's performance. All counters must count the reference footage for FU6 to a predetermined standard (0.5 Lins CCC threshold) before being given access to the current survey footage.

A summary of the surveys for the last three years is provided below (Table 5.1.4.1).

Table 5.1.4.1. A summary of Cefas UWTV surveys for FU6

Year	2016	2017	2018
Dates	21st – 28th June	19th – 26th June	19th – 26th June
Vessel	RV Endeavour	RV Endeavour	RV Endeavour
Stations used in assessment	110	110	109
Visibility	92% Good	93% Good	97% Good
Average lins CCC	0.7	0.7	0.66
Method	Geostatistics	Geostatistics	Geostatistics
Absolute abund (millions)	697	902	950
2 standard deviations (millions)	19	21	23

The last three years have seen a year on year increase in stock abundance, with abundance being just above the MSYB trigger (858 million) in 2017 and 2018 (Fig 5.1.4.2).

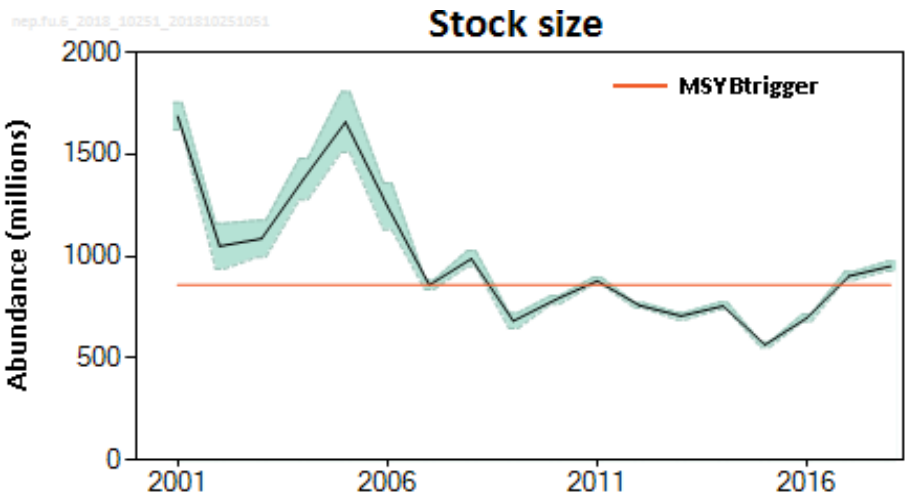


Figure 5.1.4.2 – Nephrops abundance for 2009 – 2018

Burrow densities have shown the same general distribution across the ground to previous years, with an area of higher density towards the southwest of the ground (Fig 5.1.4.3).

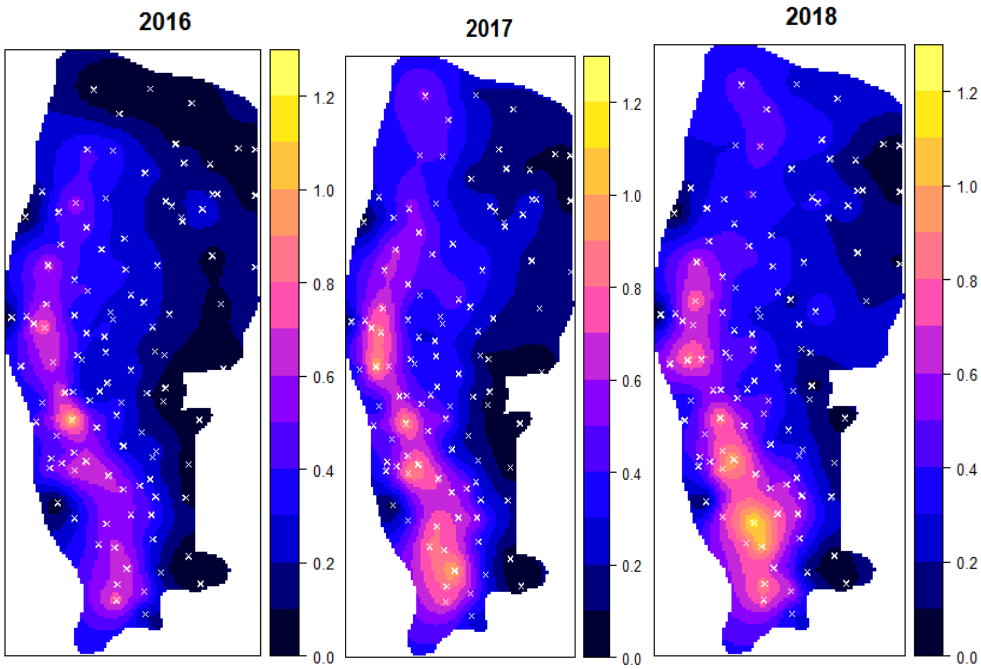


Figure 5.1.4.3 – Geostatistical outputs 2016 – 2018, maps of *Nephrops* density distribution (m²).

FU14 East Irish Sea

The FU14 survey design is based on a randomized fixed grid. In 2018 this included a total of 48 stations (Fig 5.1.4.4). The initial ground perimeter has been delimited by the combination of VMS data and BGS sediment maps. The Irish Sea *Nephrops* UWTV survey takes place onboard "RV Corystes" as part of a collaborative survey with AFBI and MI. This survey covered both the western (FU15) and eastern

(FU14) side of the Irish Sea. The survey in the East Irish Sea area is carried out using the same protocols used in UWTV surveys in the western Irish Sea. For details on gear, training and survey protocol, see the section on FU15.

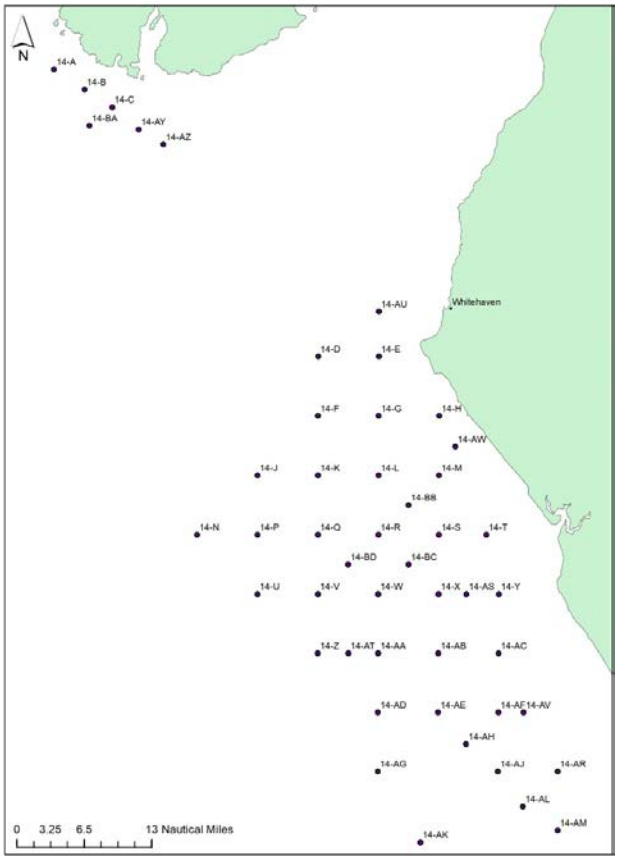


Figure 5.1.4.4 – Map showing the location of the surveyed area in the Function Unit 14 area for 2018 (48 stations).

In 2016 new stations were added to the Wigtown Bay area (14-BA, 14-AY, 14-AZ). This was done to account for an increase in effort in this area, the result of effort displacement from an area at the southern boundary of FU14 where Walney offshore windfarm has been developed. The effort in Wigtown Bay increased from 1.9% in 2015 to 6.6% in 2016 of the overall fishing effort in FU14.

Two stations have been dropped from the survey area (14-AK, 14-AG) in 2016 due to the construction of Walney offshore windfarm extension. These have been permanently removed from the survey grid.

In 2018 three stations were removed from an area offshore from Workington (not shown on current map) as recent VMS data showed little effort in this area. These stations were relocated in the main grid (14-BB, 14-BC, 14-BD) to better sample an area of the FU which consistently has high densities from year-to-year.

A summary of the surveys for the last three years is provided below (Table 5.1.4.2).

Table 5.1.4.1.2. A summary of Cefas UWTV surveys for FU14.

Year	2016	2017	2018
Dates	25th July – 3rd Aug	6th – 8th Aug	6th – 8th Aug
Vessel	RV Corystes	RV Corystes	RV Corystes
Visibility	84% Good, 16% moderate/poor	87% Good, 13% moderate/poor	60% Good, 40% moderate/poor
Method	Geostatistics	Geostatistics	Geostatistics
Absolute abund (millions)	432	579	513
95% confidence interval (millions)	106	89	118

The last three years have seen a stock abundance remaining above MSYBtrigger (Fig 5.1.4.5), with the current estimate of abundance being 513 million.

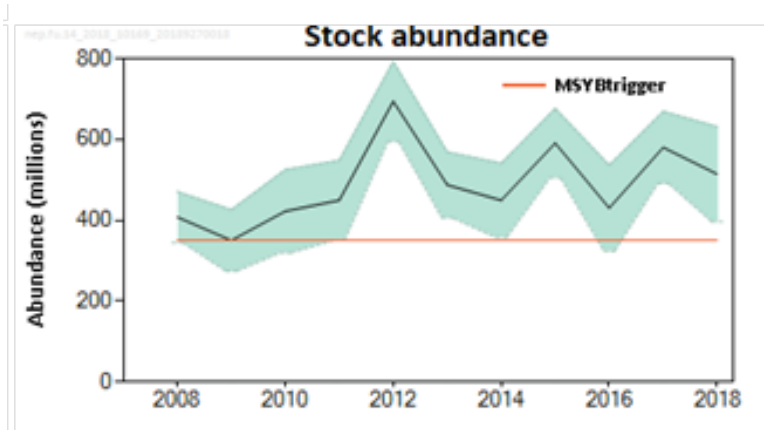


Figure 5.1.4.5 – Nephrops abundance for 2009 – 2018.

Burrow densities have shown the same general distribution across the ground to previous years, with an area of higher density towards the centre of the ground (Fig 5.1.4.6).

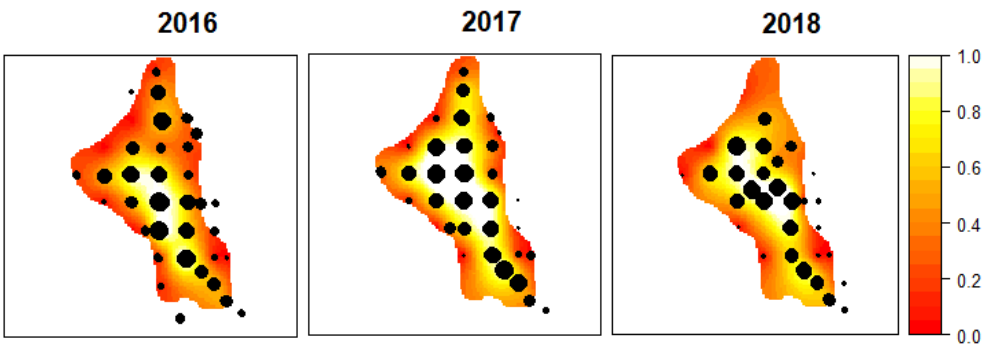


Figure 5.1.4.6 – Geostatistical outputs 2016 – 2018, maps of *Nephrops* density distribution (m²).

Conclusions/Recommendations:

As in other *Nephrops* stock there are a number of generic research questions related to occupancy and edge effect bias that needs still to be investigated.

- For FU 14 and FU6 more accurate mapping of the spatial extent of the grounds and fisheries, this includes having positional data for < 12 meter vessels and more survey data in the boundary areas to better define these grounds.
- For FU 14 there is a need to improve the spatial coverage and sampling of landings and discards, this includes increasing the sampling levels to covers Northern Irish vessels, as the current sampling is mainly focused on local vessels form Whitehaven port.
- For FU14 there is a need to get area specific length-weight and maturity data to validate the parameters used for this FU.

5.1.5 Denmark and Sweden

FU3-4: Skagerrak and Kattegat

(Kai Wieland, Mats Ulmestrand)

A new stratification was implemented in 2017 which is described in the last years report. Sweden used also DTU Aqua's RV Havfisken with the Danish HD camera and sledge equipment outside the Swedish 4 nautical mile limit and used inside this limit RV Asterix with the old analog video recording system in 2017 and in 2018.

The 2017 survey was carried by Denmark mainly during April in strata 1, 2, 5, 7 and 8 with RV Havfisken and by Sweden during June in strata 3, 4, 6 and 9 with RV Havfisken outside the Swedish 4 nm limit and with RV Asterix inside the Swedish 4 nautical mile (nm) zone with also included stations in the creel area. Denmark completed 110 stations but 6 stations were not suitable for analysis due to poor visibility. Similarly, Sweden encountered difficulties with water clarity and rocky bottom and conducted 75 out of the 98 planned stations in the standard strata, and performed 14 additional valid stations in the creel area. The overall achieved coverage for both countries with stations suitable for analysis in the standard strata was 85 % of the planned stations. The distribution of *Nephrops* bias corrected density is shown in Figure 5.1.5.1. With the inclusion of new strata and extension of existing strata, the total survey area suitable for *Nephrops* amounted to 13490 km^2 (without creel area). The average bias corrected *Nephrops* burrow density was 0.399 n/m^2 with an overall relative standard error (OECV) of 3.75 %. The corresponding population estimate is 5160 million individuals. This is a considerable increase compare to the previous year but its interpretation is difficult due to the change of the survey stratification and the extension of the survey area.

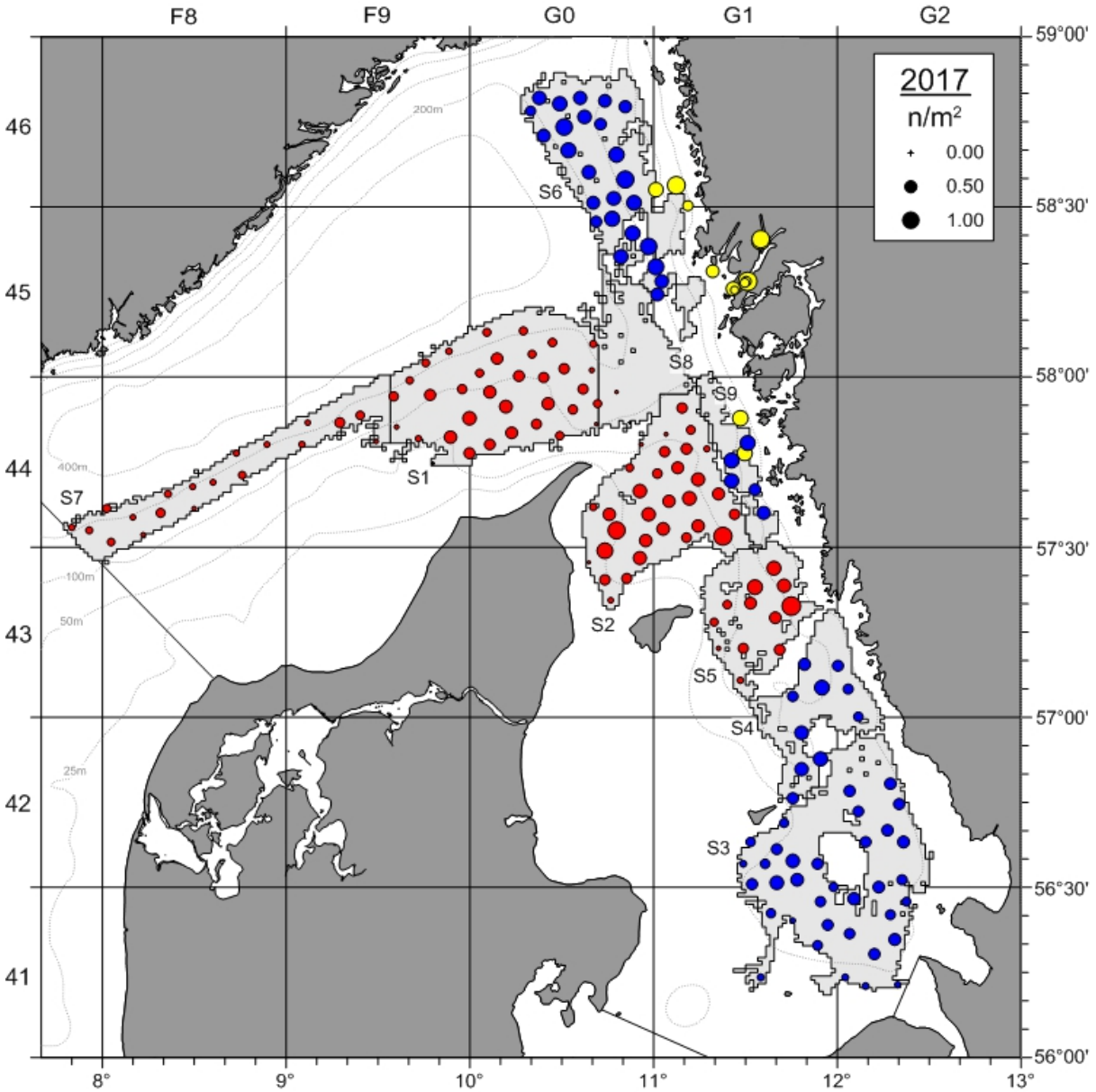


Figure 5.1.5.1. ***Nephrops*** **bias corrected densities in FU3-4 in 2017 (S: stratum; red circles: Denmark, blue and yellow circles: Sweden).**

In 2018, Denmark conducted its survey again with RV Havfisken in April with 109 stations of which 103 stations were valid for analysis. Sweden covered 75 stations outside the Swedish 4 nm zone with RV Havfisken and 10 stations in coastal waters and the creel area with RV Asterix in June. So far, the burrow counting has been completed for Denmark only and the resulting *Nephrops* density distribution is shown in figure 5.1.5.2. Compared to 2017, high densities were observed in stratum S2 whereas not much change was found for the other strata covered by Denmark.

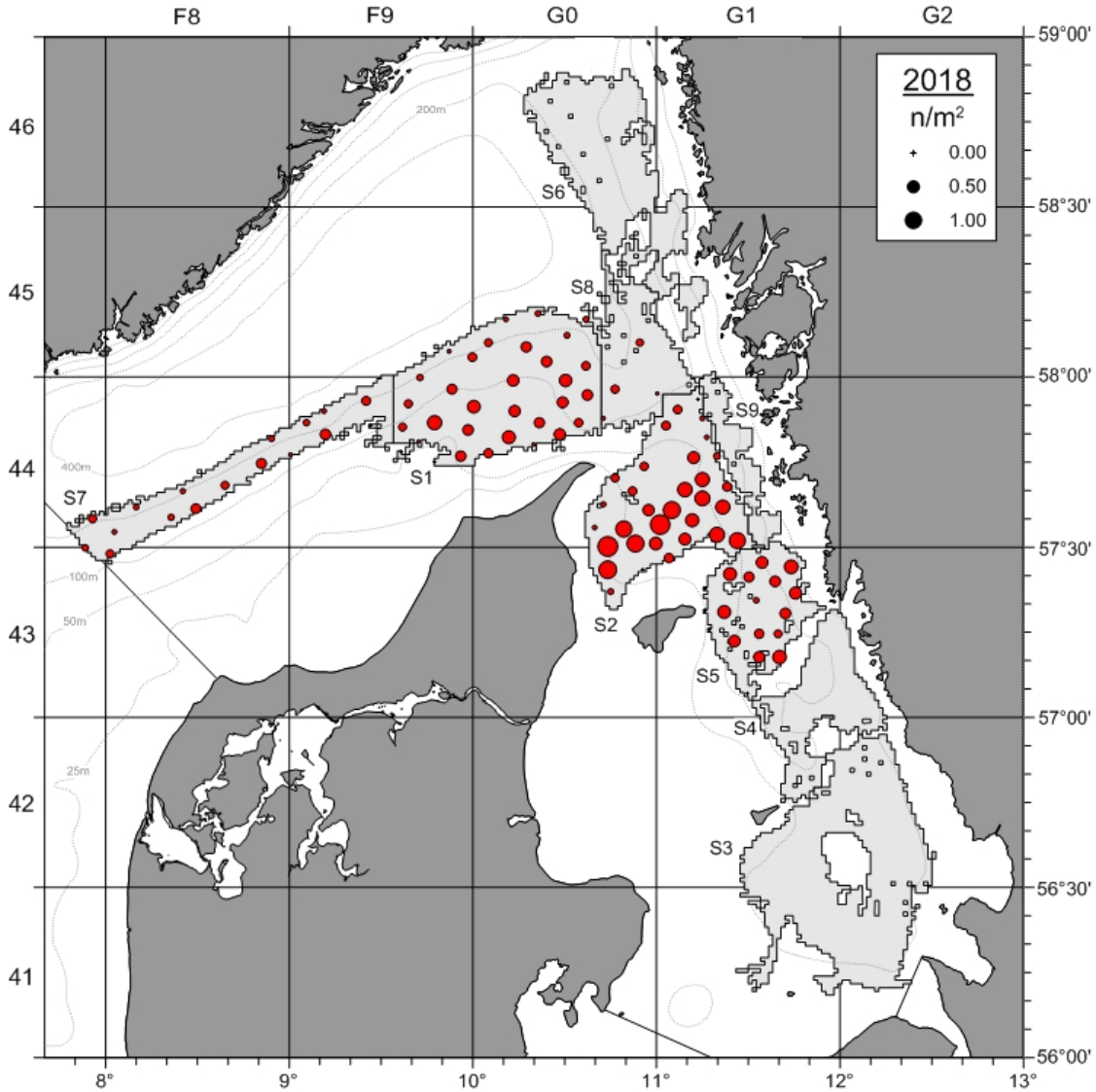
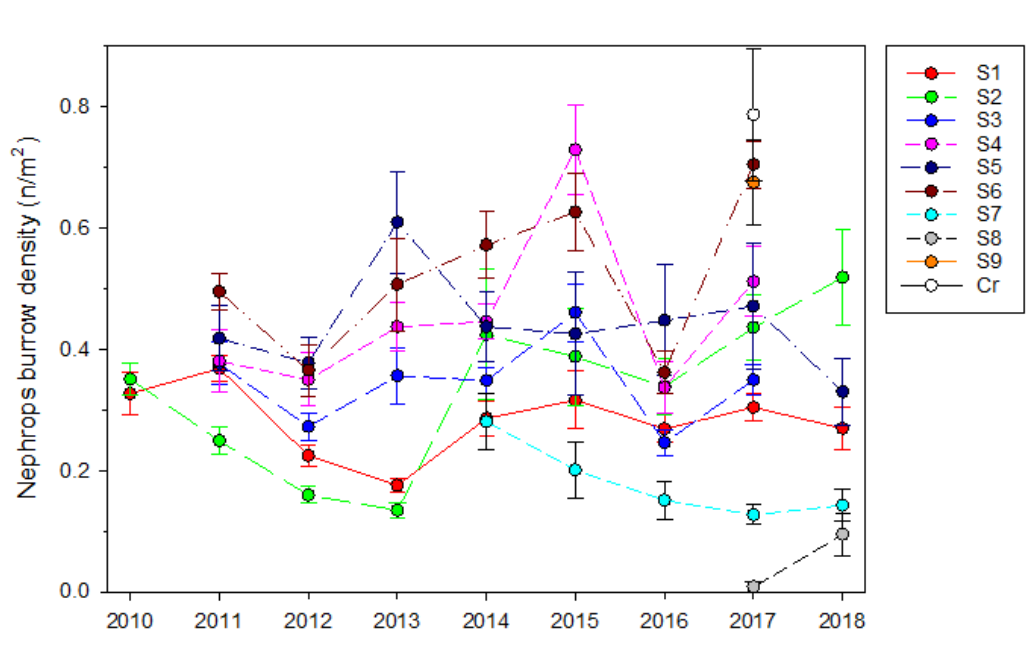


Figure 5.1.5.2. ***Nephrops*** **bias corrected densities in FU3-4 in 2018 for the Danish survey (S: stratum).**

The entire time-series of *Nephrops* densities by stratum and average densities as used in the advice for the survey is presented are Figure 5.1.5.3.



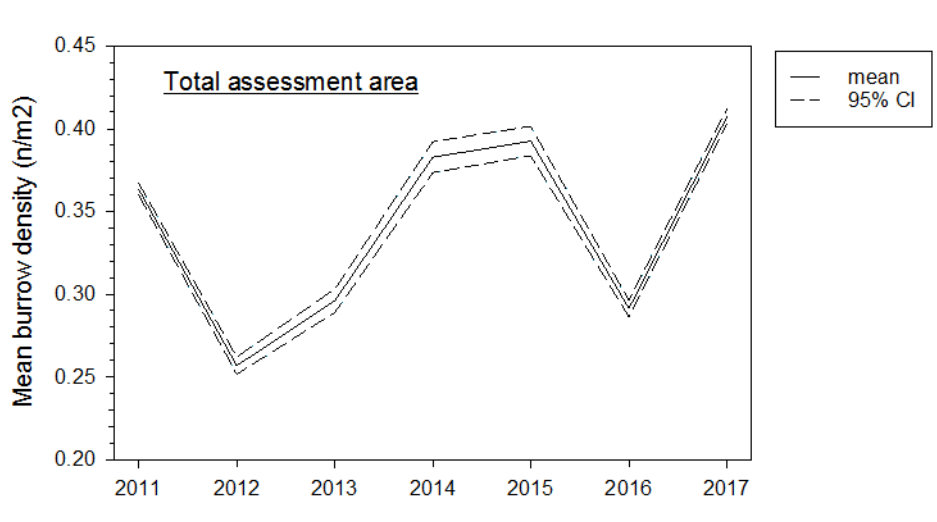


Figure 5.1.5.3 ***Nephrops*** **bias corrected densities in FU3-4 (S: stratum; Cr: creel area; mean ± 1 standard error).**

Conclusions/Recommendations:

- No further changes of survey design except for a possible increase of stations in the new strata.
- It would be desirable if the Swedish results would be available prior to the next year meeting which would then also allow to discuss the station allocation for the coming year in time before applications for Swedish waters have to be prepared.
- Establish a new set of reference footages which should then also include strata sampled by Sweden (the existing set contains only Danish stations) preferably sampled with a HD system. Selection and analysis of the reference footages is planned to be done during for a bilateral workshop in spring 2019. The proposed workshop need an external expert present.

- The collaboration between the readers of the two countries should continue whereby the stations read by the two countries may be randomized.
- Time-series of *Nephrops* densities should be provided as violin plots by stratum and for the total survey area.

FU 33 Off Horns Rev

(Kai Wieland)

Denmark established an UWTV survey in 2017 in this FU for which no fishery-independent had been available so far and advice was based on an assumed average burrow density of 0.1 n/m² taken from FU 7 (Fladen Ground). The survey design follows the approach used for FU 3-4 and is described in the last years report.

The survey is carried out with RV Havfisken with 24h operation. In 2017, 70 stations were planned of which 66 stations were conducted and 59 stations were suitable for analysis. In 2018, 85 stations were planned and all of were conducted and were valid for burrow counting due to much more favourable weather conditions than in the year before. A bias correction factor of 1.1 was assumed and the resulting distributions of *Nephrops* density for the two years are shown in (Figure 5.1.5.4).

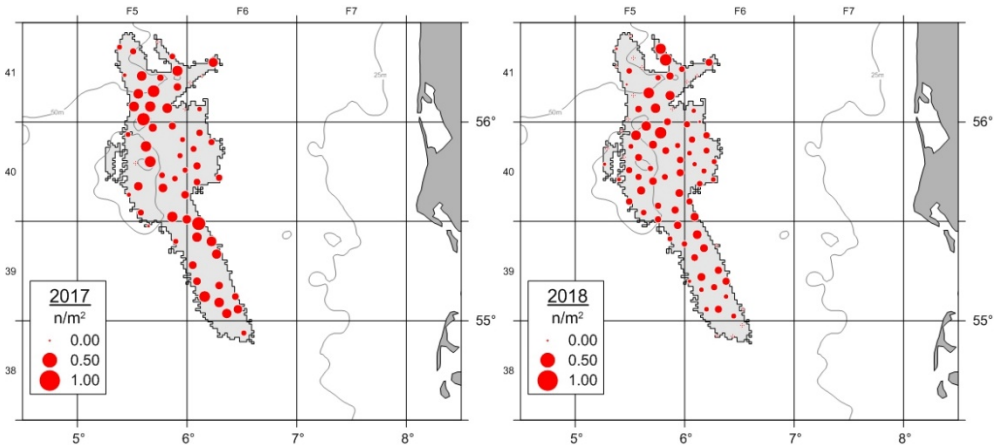


Figure 5.1.5.4. *Nephrops* bias corrected densities in FU 33 in 2017 and 2018.

Mean *Nephrops* density amounted to 0.1269 n/m² corresponding to a population estimate of 728 million individuals, and the CV of these estimates was 9.6 % for 2017. For 2018, mean density was 0.0744 n/m², abundance was 427 million and the CV was 10.1 %.

Counting of *Nephrops* burrows for this FU is difficult for the Danish readers due to a high presence of small burrows belonging to other species not occurring in the FU 3-4 which is the area the Danish readers are best trained for. A set of reference footages has been established for comparative reading with an external counter from an area similar to FU 33 which e.g. could be FU 7.

At the moment, the continuation of the survey is only secured for 2019. Considering that the actual Danish share of the *Nephrops* quota is just 35 % and the total Danish landings from this area are relative low, the survey may come to end after 2019 unless other countries fishing *Nephrops* in this area will contribute to the survey.

Conclusions / Recommendations:

- Confirm the adequacy of the selected reference footages through comparative counting by the Danish readers and an external expert.
- Determine bias correction factor.
- Provide violin plots for *Nephrops* densities by year.

5.1.6 Spain

(Yolanda Vila, Candelaria Burgos)

FU 30_Gulf of Cadiz

Survey results

This was the fifth annual survey in the time-series of ISUNEPCA UWTV surveys in the Gulf of Cadiz (ICES Division 9a, FU 30) carried out by the Spanish Oceanographic Institute (IEO). The first survey in 2014 is considered exploratory. The survey took place on board RV Angeles Alvariño between 2sd and 14th June.

The specific objectives of this multidisciplinary survey are listed below:

1. To obtain estimates of Nephrops burrows densities.
2. To confirm the boundaries of the Nephrops area distribution
3. To obtain estimates of macro benthos species and the occurrence of trawl marks and litter on the sea bead.
4. To collect oceanographic data using a sledge mounted CTD.
5. To collect sediment samples.
6. Seabed morphological and backscatter analysis.

The design of the survey followed a randomized isometric grid at 4 nm spacing. Since 2016, stations are allocated in the grid in a rhomboidal way. A total of 70 stations were planned covering the *Nephrops* area distribution established in the last benchmark (ICES, 2017a) (Figure 5.1.6.1). The ground perimeter has been established using a combination of VMS and logbook data, *Nephrops* abundance data from IBTS surveys series and bathymetric information (Vila et al., 2016). The *Nephrops* area corresponds to 3000 km^2. Stations ranged from 90 to 650 m depth. A couple of stations were planned beyond the deeper *Nephrops* limit and considerate as exploratory (black stars in the Figure 1) but they could not be carried out because of the lack time. In this area, there is not fishing activity according to the VMS information available but the IBTS surveys information shows presence of *Nephrops*. A few stations were re-do due to problems with the visibility from the recent fishing activity as well as technical problems (4 stations). However, 8 stations were considered definitely null after to be reviewed the videos. So, 60 of 70 stations were used in the geo-statistical analysis. As last year, a number of hauls from beam trawl were planned in order to know the presence of other burrowing fauna which co-occurring with *Nephrops* and that could be source of confusion in the identification of *Nephrops* burrows. A total 7 beam trawl was carried out, mainly in the shallowest border (Figure 5.1.6.1). The locations of the sediment sampling and TOPAS sub-bottom profiles are shown in figure 5.1.6.2.

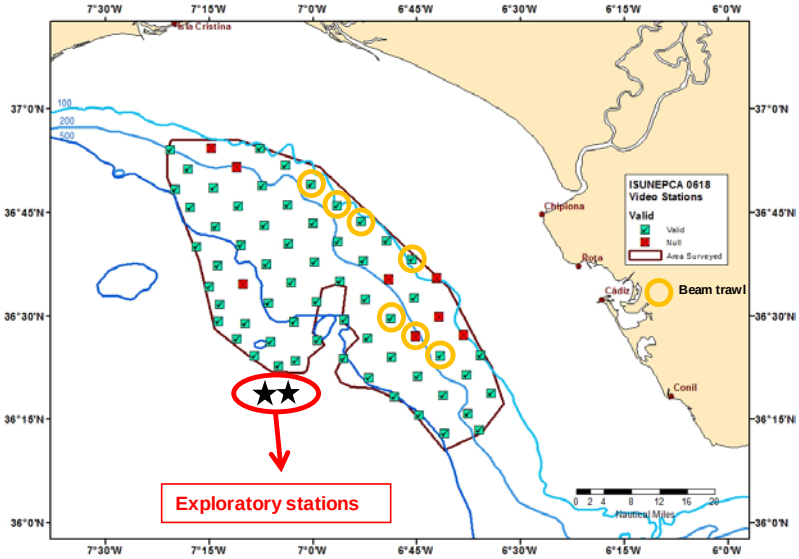


Figure 5.1.6.1. TV stations grid planned and hauls using beam trawl carried out in 2018 ISUNEPCA UWTV survey.

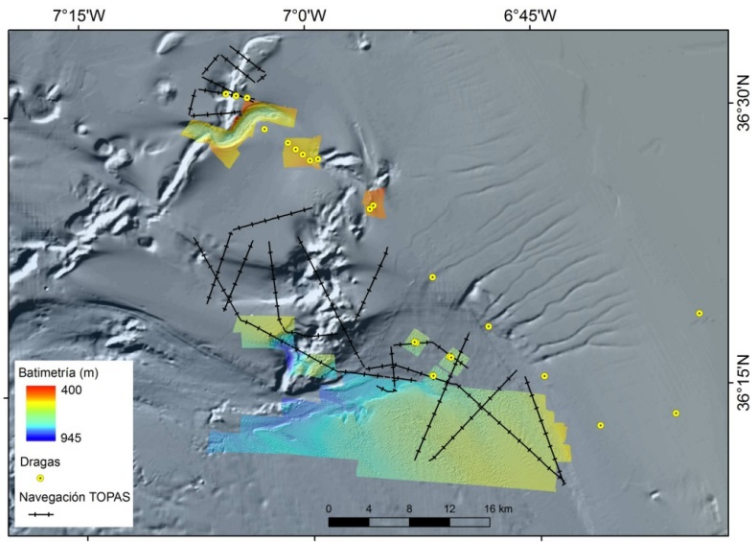


Figure 5.1.6.2. Sediment sampling (yellow points) and TOPAS sub-bottom profiles in ISUNEPCA UWTV survey 2018.

According to the SGNEPS (ICES, 2009) recommendations, previously to the survey, all scientists were trained using training material and reference footage for the FU 30 created just after WKNEPS in 2016 (ICES, 2017b). However, this reference set was considered not appropriated and a new reference footage have been created during WKNEPS 2018 (ICES, 2018), which will be used next year.

All recounts were conducted by three trained "burrow identifying" scientists independent of each other. Lin's CCC R script was implemented and applied to all recounts to identify those stations which

required additional counts. Only stations with a threshold lower than 0.5 were reviewed again by consensus among the three counters.

Footages were also used to count other megafauna species by other different team. The abundance was estimated using a range system composed by 6 categories from absent (0 indiv.) to extremely abundant (>100 indiv.). Trawl marks and litter were recorded as presence/absent. This task has been not finished before WGNEPS. Nevertheless, the results will provide very valuable information to characterize the habitat in the *Nephrops* area distribution in the Gulf of Cadiz in the framework of the Marine Strategy (MFSD).

Figure 5.1.6.3 shows the *Nephrops* density (adjusted to account for bias factors) for 2018 in this FU. The density ranged between 0 and 0.35 burrows/m^2 and the average burrow density was 0.12 burrows/m^2. The highest densities were observed in the western part of the area (Figure 3). In the shallowest edge the visibility is very poor and the *Nephrops* density is low according to the VMS data and IBTS surveys series generating a high uncertainty in the *Nephrops* burrows identification. Additional information obtained from the beam trawl activity carried out in 2017 and 2018 indicated absence of *Nephrops* in hauls carried out at depth lower than 200 m (Figure 5.1.6.3). Therefore, the stations located in this edge of the area surveyed were considerate stations with zero *Nephrops* density in the geostatistic analysis, as the previous year.

The final modelled density surfaces in the UWTV surveys time-series (2015-2018) are shown as a heat maps and bubble plots in Figure 5.1.6.4. Table 5.1.6.1 shows the summary statistics from the geo-statistical analysis using ArcGis (Ordinary kriging and positive anisotropy). This year the number of stations used in the geostatistical analysis was a little lower than the previous years (60 instead 62) since a larger number of stations were considered null. The abundance estimate derived from the krigged burrow surface (and adjusted for the cumulative bias) was 329 million burrows with a CV of 6% in 2018 (Table 5.1.6.1). Stock abundance has shown a small decrease in 2018 but the spatial pattern of burrow density is consistent in last two years.

The approach based on UWTV survey to generate catch options in FU 30 was accorded in WKNEPS 2016 (ICES, 2017b). However, MSY reference points are undefined for this stock because of the poor fits in the length-frequency model, normally used for calculating F_{MSY} for category 1 *Nephrops* stocks. In absence of stock specific MSY harvest rates the basis of the advice for this stock follows the category 4 approach for *Nephrops*. A workshop on *Nephrops* reference points is planned for 2019. If stock specific MSY reference points can be estimated during this WK the stock will meet the requirements for category 1 assessment.

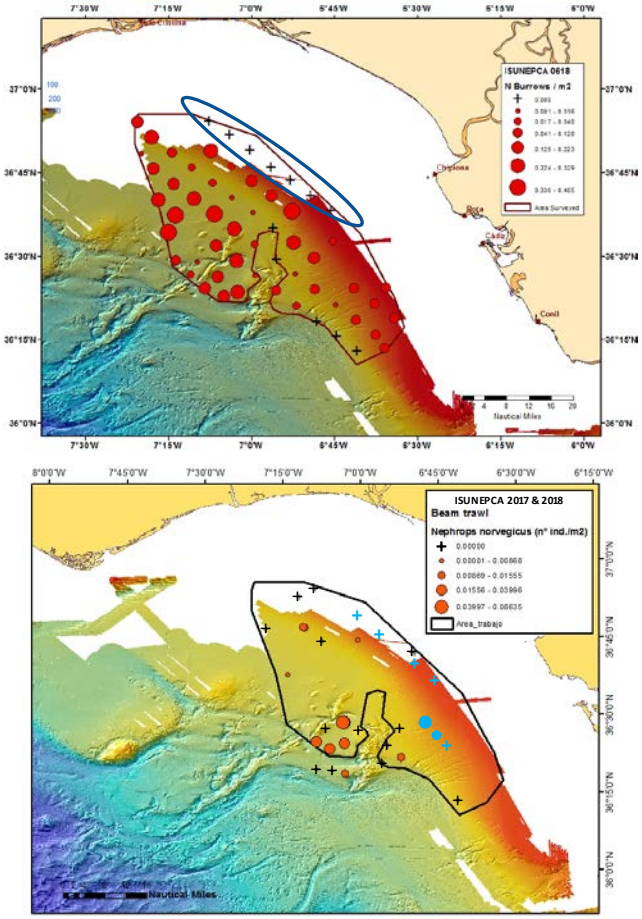


Figure 5.1.6.3. ***Nephrops*** **density adjusted to account for bias factors for 2018 UWTV survey (above), blue ellipse shows stations where zero** ***Nephrops*** **is assumed;** ***Nephrops*** **density from beam trawl (below) (blue symbols represents survey in 2018).**

Table 5.1.6.1. Results summary table for geostatistical analysis of UWTV surveys in FU30.

Year	Landing in number	Total discard in number*	Removals in number	UWTV Abundance estimates	95% conf. intervals	Harvest Rate	Mean weight in landings	Mean weight in discard	Discard rate	Dead discard rate
	millions	millions	millions	millions	millions	%	g	g	%	%
2014**	0.48	0	0.48	282		0.2	31.2	NA	0	0
2015	0.80	0	0.80	298	45	0.3	30.8	NA	0	0
2016	5.35	0	5.35	233	34	2.3	23.2	NA	0	0
2017	5.95	0	5.95	370	63	1.6	23.4	NA	0	0
2018				329	39					

* Discards are considered negligible and are not included in the assessmet

** UWTV survey in 2014 is considered exploratory. UWTV abundance estimate is not adjusted by the cummulative bias

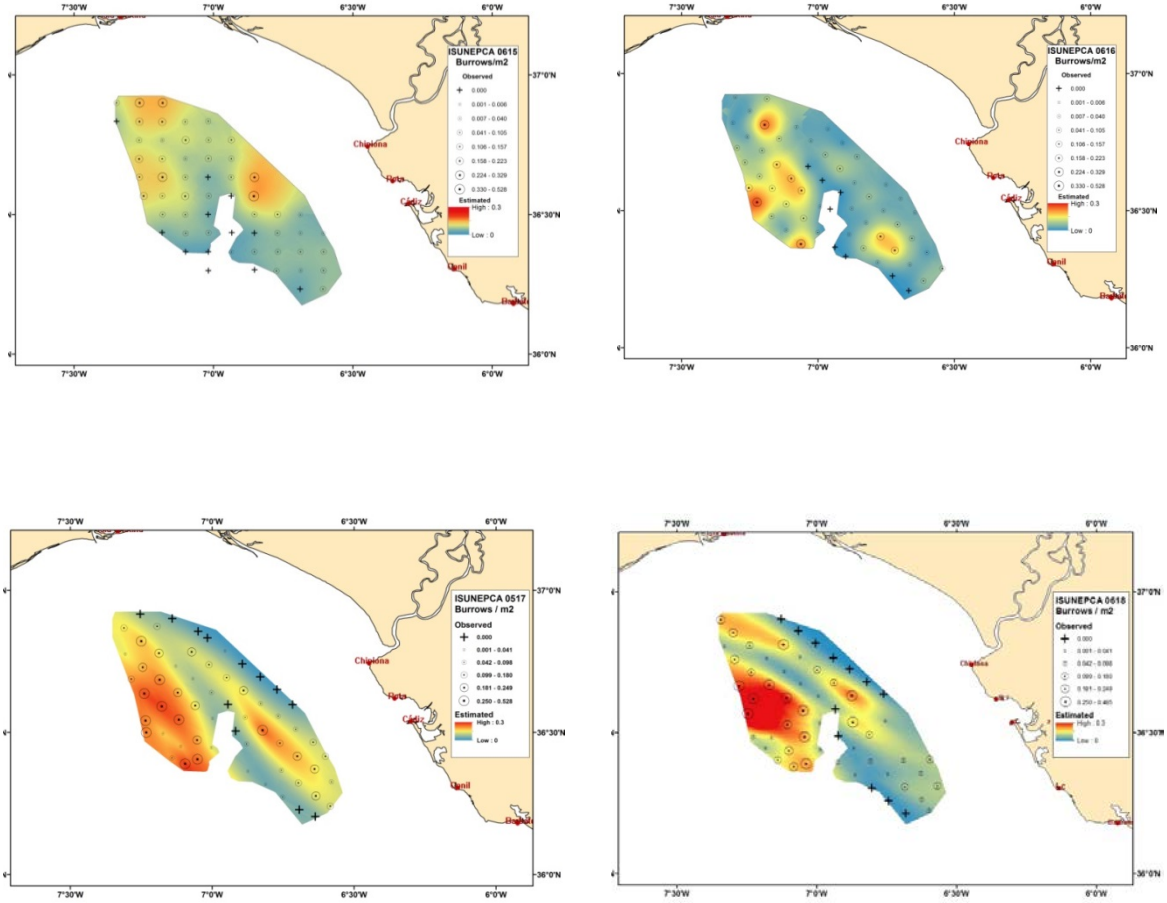


Figure 5.1.6.4. Bubble plot of the burrow density observations overlaid on a head map of the krigged burrow density surface for UWTV survey series (2015-2018). Station positions with zero density are indicated using a +.

Equipment developments

New equipment was tested and used in 2018 UWTV survey. The sledge is a stainless steel structure AISI 316L on which all equipment is mounted. It has a main structure where two types of skates can be coupled according to the mode of operation (towed way or suspended way) (Figure 5.1.6.5). For the quantification of *Nephrops*, it is used skates to be towed on the bottom while skates for operations with the sledge suspended are used for habitat studies on non trawlable bottoms. The sledge is provided with holders articulated in two axes and they allow its displacement across the structure. The video camera holder allows varying the angle of inclination to the background (angle used 45°).

This equipment has a HD life camera, 4K UHD recording camera, 2 photo cameras (20 Mpixel) which can be use in order to obtain the same scene since two different angles, 4 spotlights with independent intensity control, 3 point laser forming a triangle of 70 mm side inside of the recording camera cylinder and 2 line laser on the structure to confirm the field of view (FOV) whose distance can be graduated between 30 cm and 1 m (FOV used 75 cm), battery to power the equipments, CTD, altimeter and a desk unit in order to control the whole of system (see figure 5.1.6.6). Table 5.1.6.2 shows the main specifications.

Table 5.1.6.2. New equipment specifications used in ISUNEPCA UWTV survey 2018.

Life camera

- FullHD (1920 x 1080) @30 fps
- Ángulo de visión (con lente 0.67x) 63º

Recording Camara SONY Handycam
*4K Ultra HD (3840 x 2160) & FullHD (1920x1080) @ 50 fps
Lens ZEISS® Vario-Sonnar® T de 29,8 mm
*Sensor CMOS EXMOR R® 1/2.3 (7,76 mm)
*Optical zoom 10x & 15x (4K)

2 Photo Camaras
* 20.1 MPixel
*Sistema de lentes intercambiables, montura tipo E de Sony SONY ILCE
*Sensor CMOS EXMOR® type APS-C (23,2 x 15.4 mm)
*Motor BIONZ™ X
*ISO 100-16.000
*video recording capacity AVCHD

Lighting system

- 28640 lumens, distributed in 4 spotlights with individual intensity system
- Spotlights TST-OFL 7000 (Thalassatech-Oil Filled LED)

System of photogrammetry by laser
- 3 point lasers (5 mW & λ=670 nm) forming a triangle of side 70 mm
2 li l (200 W & λ 670) t d 75

Battery (Li-ion, size18650, 3.7 V & 2400 mAh = capacity 480 Wh): Authonomy between 2-12 h, charge in 2 h

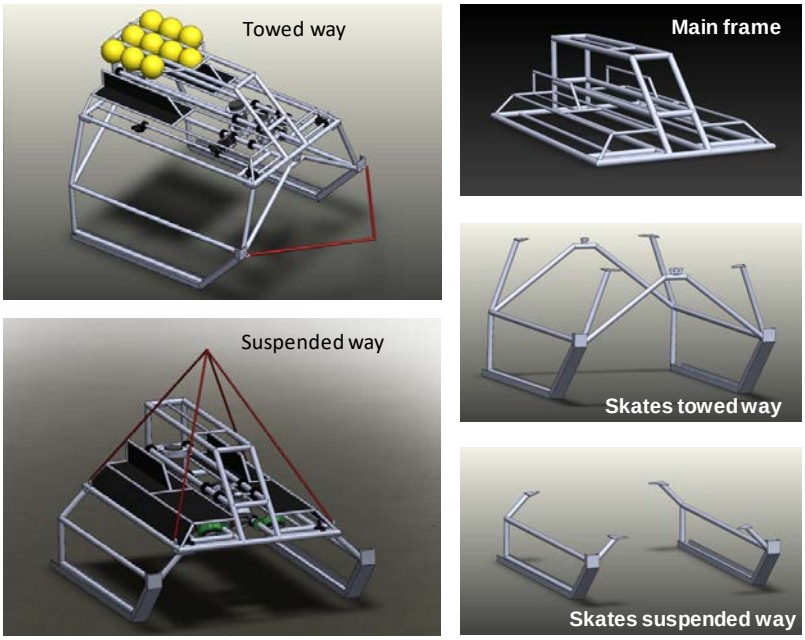


Figure 5.1.6.5. Two ways for the sledge operations: towed (Left top) for the *Nephrops* quantification and suspended way (bottom left) for the habitat studies in non trawlable bottoms.

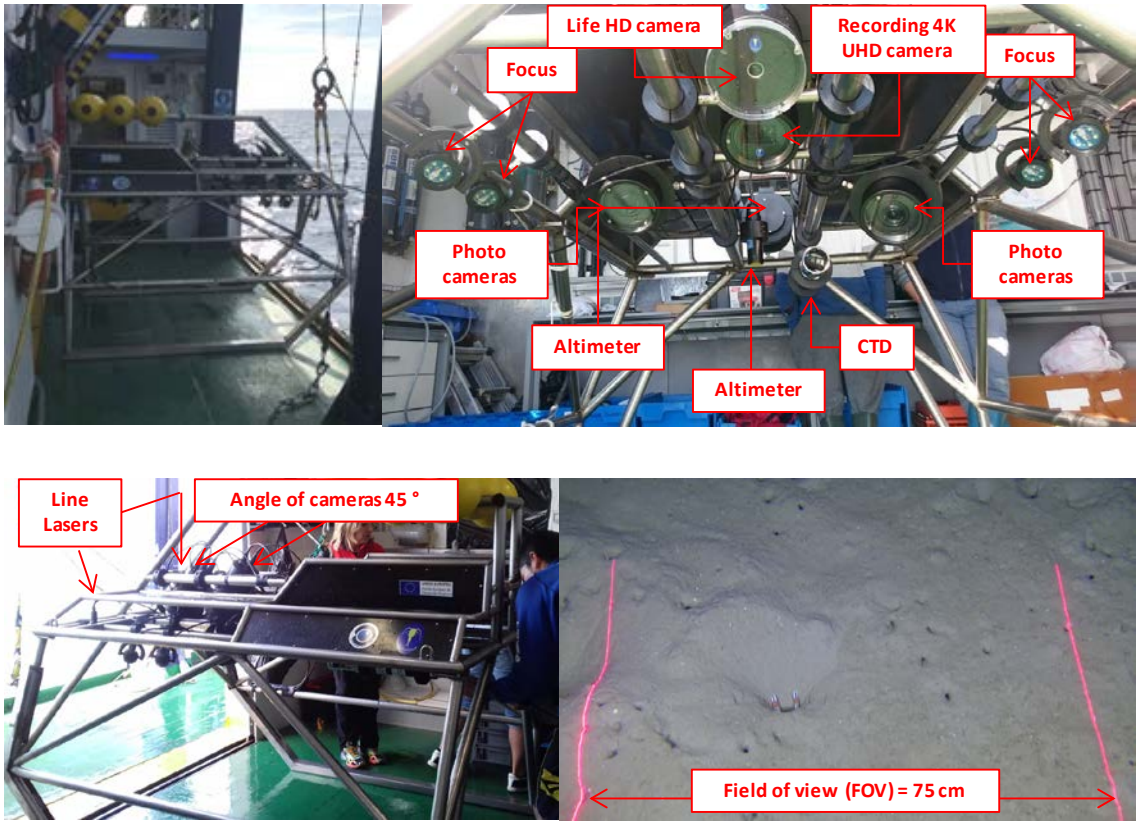


Figure 5.1.6.6. Sledge and equipment use in ISUNEPCA UWTV survey 2018.

Future issues

- Trawl data indicate co-occurring species that could be source of "burrow identification confusion", so beam trawl activity should be continued in future surveys to validate the video observations and confirm the limits of the Nephrops distribution.
- Continue carrying out exploratory stations in order to confirm the Nephrops boundaries.
- Update of the Nephrops area distribution from new information available (recent VMS, beam trawl, sediment, seabed morphological and backscatter data) should be considered.
- Stock specific FMSY reference points must be estimated for FU 30 in order to meet the requirements for category 1 Nephrops stocks.

5.1.7 Italy and Croatia

(Martinelli M., Medvešek D., Belardinelli A., Isajlović I., Angelini S., Domenichetti F., Morello E.B., Penna P., Croci C., Micucci D., Scarpini P., Guicciardi S., Santojanni A., Vrgoč N., Arneri E. …et al.)

The Adriatic Sea (GFCM Geographical Sub Areas 17 and 18) is one of the most important and productive fishing areas of the Mediterranean basin and here *Nephrops norvegicus* ranks second among all the

crustaceans caught even if showing a decreasing trend from 2005 onwards (FAO-GFCM, 2016). An important fishing ground occurs in the Central Adriatic depressions (the Pomo - or Jabuka in Croatian - Pits, part of GSA 17; Figure 5.1.7.1), which represent also a nursery for European hake (*Merluccius merluccius*) (Angelini et al., 2016). The Norway lobster stock located in this area is distinct from other Adriatic populations and is characterized by small-sized, slow-growing individuals (Froglia and Gramitto, 1982; Vrgoć et al., 2004; Colella et al. in press). Furthermore, this area represents a fishing ground shared by the Italian and the Croatian fleets (Martinelli et al., 2013; Russo et al., 2018) and has been the subject of many discussions aimed at establishing there an area closed to fishery (e.g. ADRIAMED, 2008; De Juan and Lleonart, 2010). From 2015 some protection measures were implemented by the Italian and the Croatian governments (changing various times in the definition of the closed area and the restriction measures), until GFCM established in 2018 a Fishery Restricted Area (FRA) lasting for 3 years and stated the necessity to monitor it (GFCM, 2017). The FRA is composed by 3 different zones: zone A closed to any professional fishing activity, zones B and C subject to fisheries limitations (Figure 5.1.7.1; GFCM, 2017).

After some trials carried out in 1994 and 2004 (Froglia et al., 1997; Morello et al., 2007), in 2009 CNR-IRBIM of Ancona (Italy) (formerly known as CNR-ISMAR of Ancona), in collaboration with IOF of Split (Croatia) and under the auspices of the FAO – ADRIAMED project, started a series of UWTV surveys in the Pomo Pits area. Except for 2011, a spring survey was carried out yearly from 2009 to 2017 in the entire Pomo/Jabuka area. In 2013, thanks to the Italian National Flagship Program RITMARE, the UWTV equipment owned by CNR was completely renewed and enriched with new sensors allowing the collection of environmental parameters; further improvements were made in 2015 and 2016 in order to reach a final setup (ICES, 2017a). Unfortunately, in 2018 the survey did not took place due to unavailability of the CNR's RV Dallaporta. However, the UWTV surveys are not part of the DCF for Italy and Croatia.

The footage collected during the surveys is usually analysed later in the institute lab by a team composed by Italian and Croatian scientists. Before starting the reading session, all the readers go through a training (or re-training) process aimed to familiarize with the characteristics of the footage. The training is carried out using ICES standard procedures and materials and as well as reference set footage specifically produced for the Pomo Pits area (ICES, 2017b). The analyses of the footage are carried out on a minimum of 7 minutes per station and, from 2012, the final count per minute is given by the average of the results of 3 readers (consensus readings is applied exceptionally when variability among readers is very high). The entire time-series is stored in a database built by means of the Manifold® System Release 8 software, which allows to: i) spatially visualize the data by means of a Geographic Information System (GIS) interface, ii) perform spatial analyses, iii) apply thresholds of acceptance based on statistical analyses (e. g speed, turbidity), iv) apply different biases (e.g. edge effect, fixed), v) perform post stratification experiments (e.g. using the new regulated areas), vi) prepare data for ecosystem approach use (Martinelli et al., 2017a; ICES, 2018).

During the surveys, additional trawl hauls are usually carried out by means of an experimental net in order to obtain demographic and biological data related to the *Nephrops* and other important species (Martinelli et al., 2017 a, Annex 8.2). In 2015, the Italian Ministry of agriculture and forestry entrusted CNR-ISMAR of Ancona a monitoring activity in the area by means of trawling, with the aim of an evaluation of the implemented management measures. Thus, from that year, an additional trawl survey (targeting also other species of major interest in the area, such as *Merluccius merluccius* ecc.) is carried out annually in autumn, west of the Adriatic midline (Figure 5.1.7.1; Martinelli et al., 2017b). The results of the surveys are still under review and new surveys are planned for 2019.

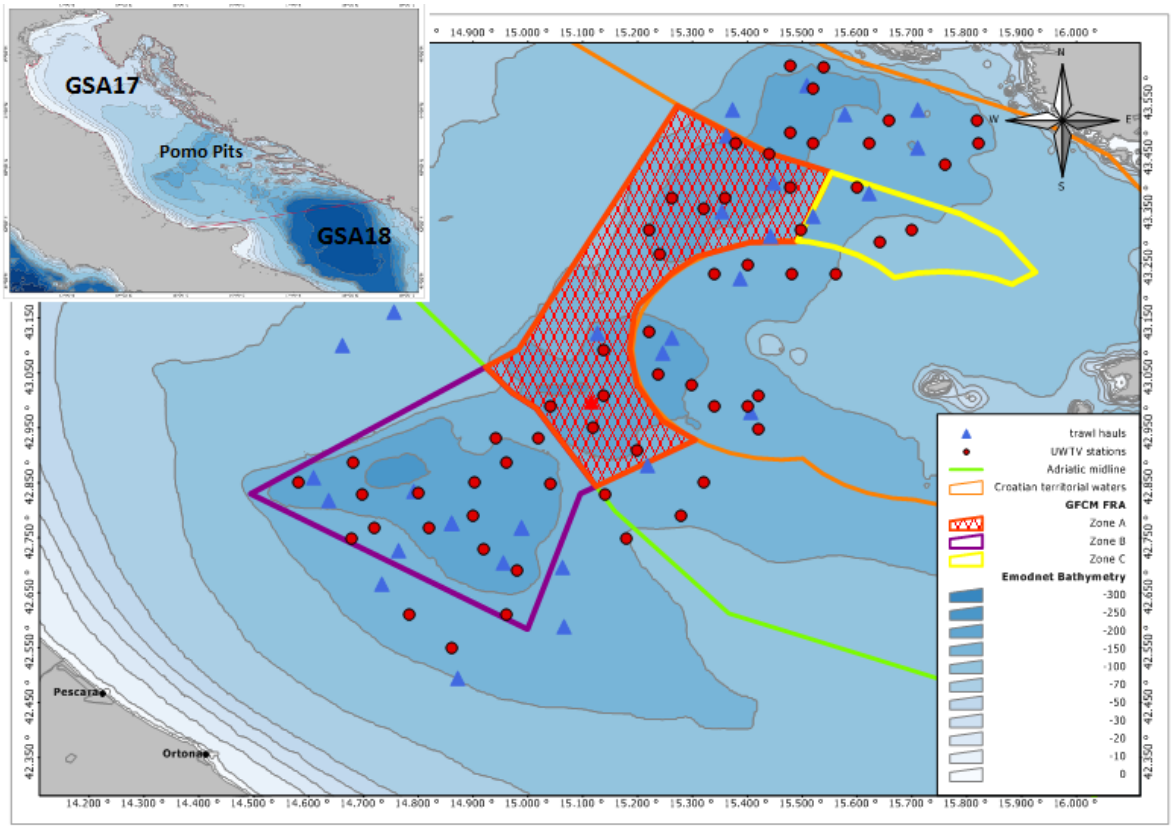


Figure 5.1.7.1. Pomo (Jabuka) Pits area in GSA 17 with indication of bathymetry (EMODNET bathymetry in meters), FRA zones defined by GFCM and location of the trawl hauls (triangles) and UWTV stations (points) carried out during the UWTV surveys.

5.1.8 France

(Jean-Phillipe Vacherot, Spyros Fifas)

FU 23-24 Bay of Biscay

1. Historical context.

The UWTV survey named "LANGOLF-TV" has been conducted since 2014 aiming to demonstrate the technical feasibility of such a survey in the local context and to identify the necessary competences and equipment for its sustainability. During the first two years, 2014 and 2015, video sampling was associated to a trawl one for the purpose of providing *Nephrops* LFDs by sex and estimating the proportion of other burrowing crustaceans (mainly *Munida*) which can induce bias in the burrows counting.

The assessment method based on UWTV data requires an unbiased and accurate calculation of the actual surface of the stock and, moreover, available dataset linked to the population dynamics (LFDs by sex for landings and discards). Both criteria are satisfied in the Bay of Biscay.

The surface involving in *Nephrops* is precisely delimited owing two information: (1) on the sedimentary structure of the sea bottom already taken into account during the former LANGOLF trawl survey on

years 2006-2013 (5 spatial strata; Figure 5.1.8.1); (2) on the systematic grid of video tracks combined with VMS data for the fishery (Figure 5.1.8.2; data source: National Fisheries Direction; compilation: Ifremer). Sampling of landings and discards (onboard and at auction) has provided yearly dataset since 1987 and mainly since 2003 owing to the monitoring of the European DCF plan (Table 5.1.8.1; Figure 5.1.8.3).

Under these favourable conditions, the Bay of Biscay was considered appropriate for an UWTV survey. The 2016's WKNEP benchmark validated the UWTV survey and the assessment combining burrows counting and the SCA model for this stock. The change of the stock status from category 3 to 1 implies annual advice instead of the biennial one applied previously.

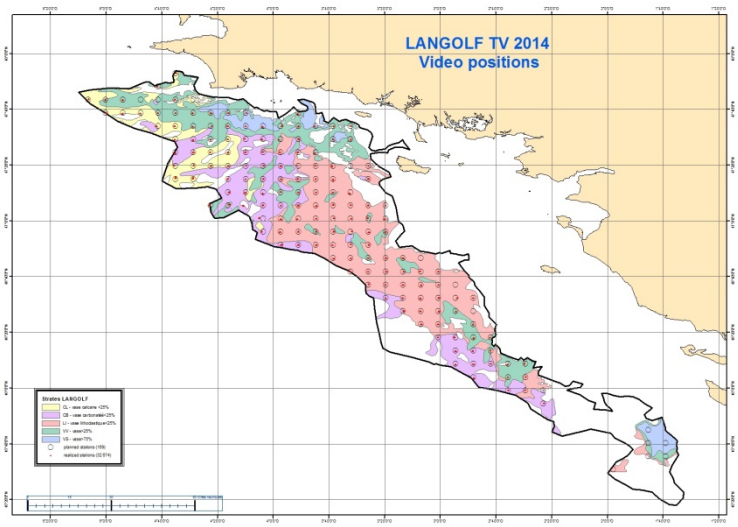


Figure 5.1.8.1. Spatial stratification of the Bay of Biscay according to sedimentary criteria as considered from the first UWTV survey onwards (2014).

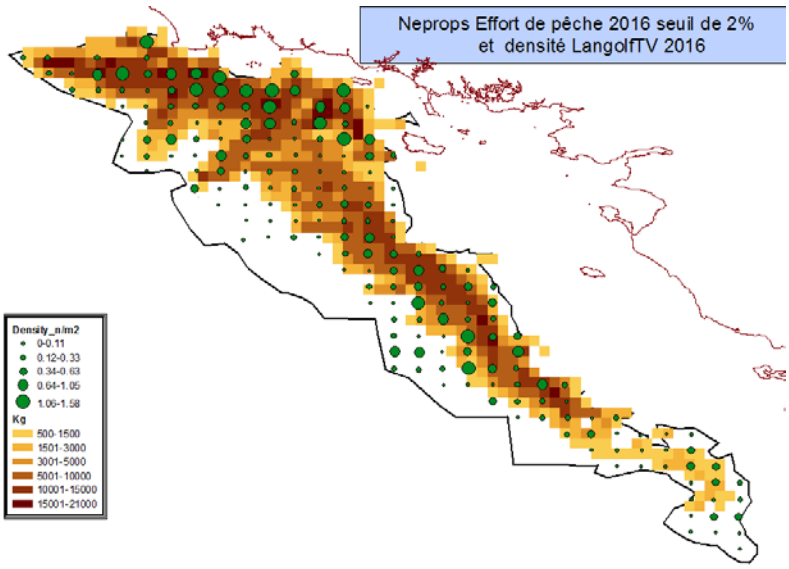


Figure 5.1.8.2. UWTV stations on a systematic grid and VMS data for retained catches of *Nephrops* (example of the year 2016; source: National Fisheries Direction; compilation: SIH Ifremer). A threshold of 2% was applied

i.e.* the coloured rectangles correspond to 98% of the nominal yearly landings for 2016. *Note: Data 2017 already processed but with not yet cartography output.

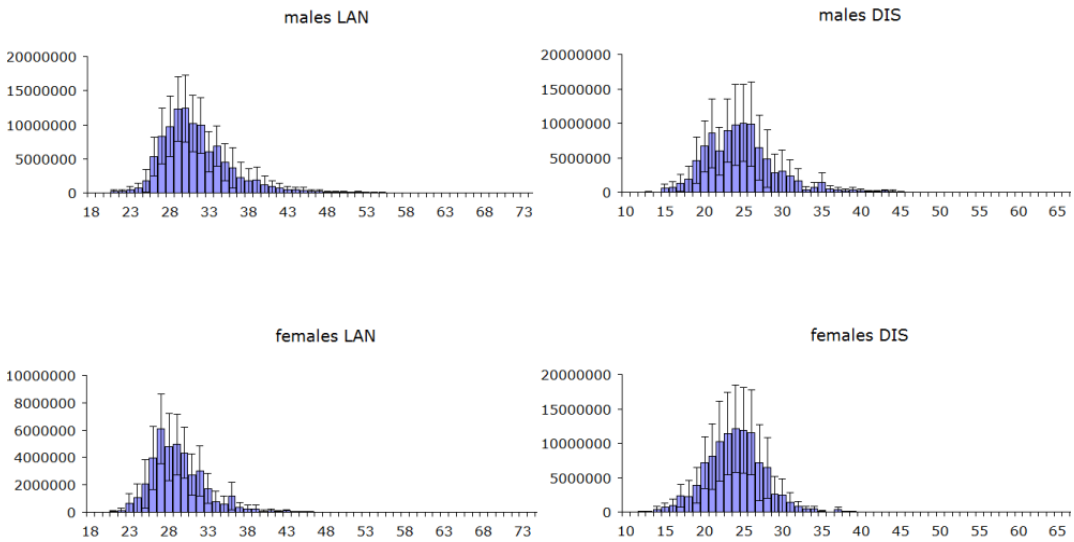


Figure 5.1.8.3. LFDs (size in carapace length, mm) for landings and discards by sex. Example of dataset 2017.

Table 5.1.8.1. *Nephrops* in the Bay of Biscay (VIIIab). Above: Landed and discarded weights. Below: Discards and landings in numbers (10^3 individuals) obtained by sampling onboard and at auction. Only years with sampling onboard are presented.

Year	Landings (1)					Total Discards		Catches
	FU 23-24 (2)	FU 23	FU 24	Unallocated (MA N)(3)	Total VIIIa,b used by WG	FU 23-24		Total
	VIIIa,b	VIIIa	VIIIb			VIIIa,b		VIIIa,b
2003	1	3564	322	49	3886	1977	*	5863
2004	na	3223	348	5	3571	1932	*	5503
2005	na	3619	372	na	3991	2698	*	6689
2006	na	3026	420	na	3447	4544	*	7990
2007	na	2881	292	na	3176	2411	*	5587
2008	na	2774	256	na	3030	2123	*	5154
2009	na	2816	212	na	2987	1833	*	4820
2010	na	3153	245	na	3398	1275	*	4673
2011	na	3240	319	na	3559	1263	*	4822
2012	na	2290	230	na	2520	1012	*	3532
2013	na	2195	185	na	2380	1521	*	3900
2014	na	2699	108	na	2807	1326	*	4133
2015	na	3425	144	na	3569	1822	*	5391
2016	na	3873	217	na	4091	2531	*	6622
2017	na	3283	129	na	3412	2387	*	5799

Year	*Discards*	*Landings*	*% discarding*
1987	268 244	288 974	48
1991	151 634	217 338	41

1998	150 995	161 549	48
2003	201 841	152 485	57
2004	222 089	139 753	61
2005	315 346	166 165	65
2006	487 288	127 942	79
2007	214 788	117 273	65
2008	198 031	115 274	63
2009	174 480	123 504	59
2010	113 530	138 120	45
2011	121 603	108 011	53
2012	117 935	101 424	54
2013	154 914	114 853	57
2014	117 930	121 594	49
2015	156 400	138 921	53
2016	200 973	161 371	55
2017	200 600	143 502	58

2. Sampling protocol.

In accordance with other routinely UWTV surveyed stocks, the sampling protocol applied since 2014 has been a systematic one advantaged by wider spatialized explorations on collected data. A distance of 4.7 nautical miles was retained similarly to the FU22 Smalls Ground. From 2016 onwards the survey duration has been longer than previously: 14 effective working days were planned (instead of 10). Thus, it has been allowed to cover for the first time the area contained in the outline of the Central Mud Bank no belonging to any sedimentary stratum: this area known as not trawled due to rough sea bottom concentrate moderate fishing effort targeting *Nephrops* (16164 km² were covered by sampling instead of 11676 km² of the historical five sedimentary strata). Moreover, accordingly to the WGNEPS 2016 recommendations, the 2017's survey covered a wider area (>28000 km²) exceeding the outline of the historical limits of the Central Mud Bank in order to accurately define the actual limits of the fishery (Figure 5.1.8.4). On this basis, 219 stations were sampled in 2017 among them 197 were validated and 124 were strictly contained in the 2016's area retained for the stock assessment. In the 2018's UWTV survey, an

additional area of ≈2200 km² was investigated with 31 validated stations added to the 184 ones contained in the 2016's benchmarked area of 16164 km².

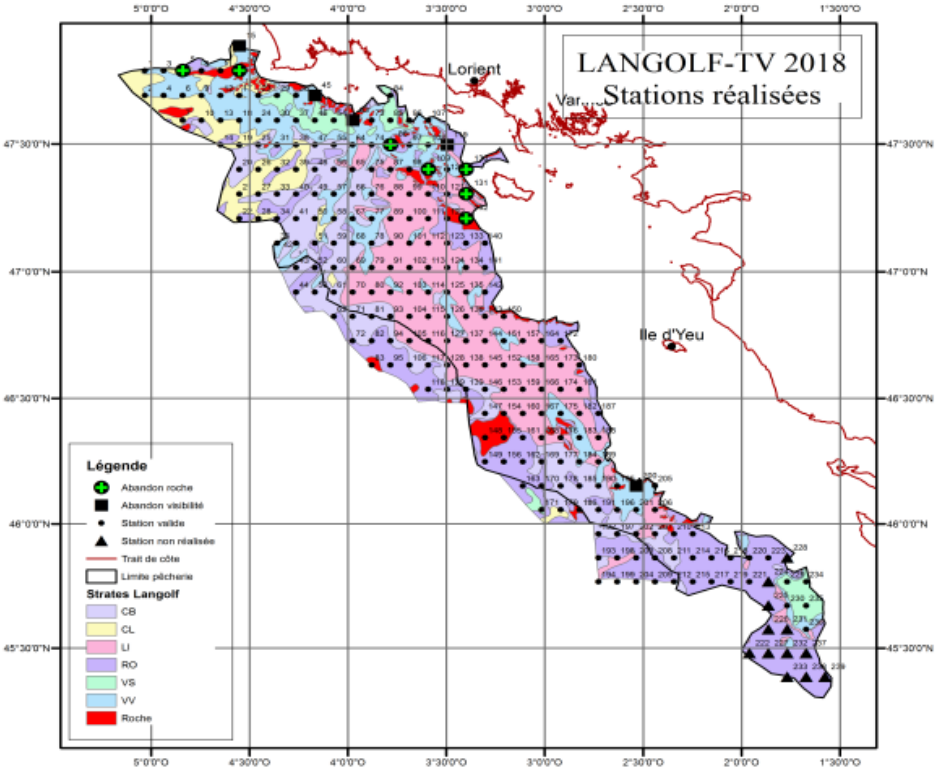


Figure 5.1.8.4. UWTV stations on a systematic grid for the 2018's survey.

In 2018, LANGOLF-TV was carried out on 13 actual days (April 19 - May 2). Six scientists participated on the on-board work. As the project was planned owing to a partnership with the "Marine Institute" (Republic of Ireland) one expert scientist and one electronics technician from Ireland joined the team. The equipment (sledge, computing hardware, screens, recorders) were provided by the "Marine Institute" (Figure 5). The sledge is based on the Scottish material (2.5 m*2.7 m*2.5 m; weight=80 kg); its speed is around 20 m/min.

Table 5.1.8.2. UWTV survey for 2018. Status of abandoned or cancelled stations.

LANGOLF-TV 2018 - Stations abandonnées			
Station	Stn annulée (visibilité)	Stn annulée (roche)	Stn abandonnée (panne sur câble)
5		X	
15	X		
16		X	
45	X x2		
63	X x2		
86		X	
109		X	
119	X x3		
130		X	
131		X	
132		X	
200	X		
222			X
224			X
225			X
226			X
227			X
228			X
231			X
232			X
233			X
237			X
238			X
239			X
Total	5	7	12

The provisional absence of reference footage in the Bay of Biscay implies the use of other support coming from grounds with similar conditions (density of burrows) to the Bay of Biscay: the Smalls grounds (FU22, Celtic Sea, UWTV surveyed since 2006) was chosen. A validation by the test CCC (Figure 5.1.8.6) allows to decide on the conformity or not of each reader.

Acquiring images on the sea bottom requires a preliminary use of multibeam sounder aiming to determine the nature of the sediment and to avoid technical problems due to rough ground. The recording starts when the sledge reaches the adequate speed (~0.8 knots), the contact with the sediment is conform although the visibility was less satisfactory in 2018 than in recent years. Recording lasts 10 min even with no *Nephrops* burrows on the track; 7 min minimum are necessary for the validation of the footage.

3. Results.

3.1. Method.

More details can be found in Cochran (1977), Frontier (1983). The stratified sampling plan allows to calculate a ratio estimator (noted Y) of two variables, the numbers of burrows by video track and the surface of the track:

$$Y = \sum_{h=1}^{ns} Y_h = \sum_{h=1}^{ns} S_h . \frac{\sum_{i=1}^{nh} X_{ih}}{\sum_{i=1}^{nh} S_{ih}}$$

with:

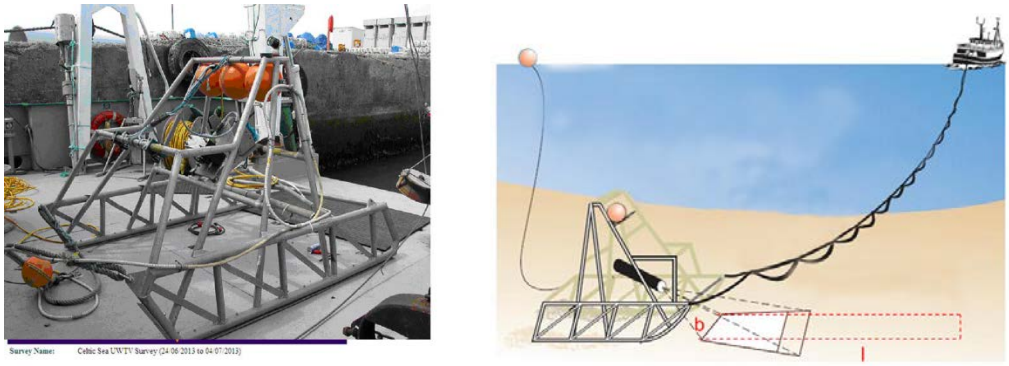
h= stratum [h=1,…,ns] (ns=5 or 6); i= station by stratum h [i=1, …, n_h]; S_h= total surface of the stratum h; s_{jh}= surface for the station i, stratum h; x_{ih}= toal number of burrows by station i in the stratum h (by adding the total recorded and validated minutes by station averaged according to the number of observers usually equal to 2)[2]

The variance of Y, noted V[Y], is given by:

$$V[Y] = \sum_{h=1}^{ns} V[Y_h] = \sum_{h=1}^{ns} \left[\frac{S_h}{\sum_{i=1}^{nh} s_{ih}} \right]^2 . [nh.\left(\frac{Y_h}{S_h}\right)^2 . V[s_{ih}] + nh.V[x_{ih}] - 2.nh.\left(\frac{Y_h}{S_h}\right) Cov[x_{ih}, s_{ih}]$$

with $V[x_{ih}]$, $V[s_{ih}]$ and $Cov[x_{ih}, s_{ih}]$ variances and covariance of x_{ih} and s_{ih}.

[2] The stratified estimator was also investigated under a sub-sampling plan (primary unit: station; secondary unit: observer*minute). It was proved that including the 2nd level increases the total variance only by 1.8-2.2%; thus, the stratified plan is further developed on only one sampling level.



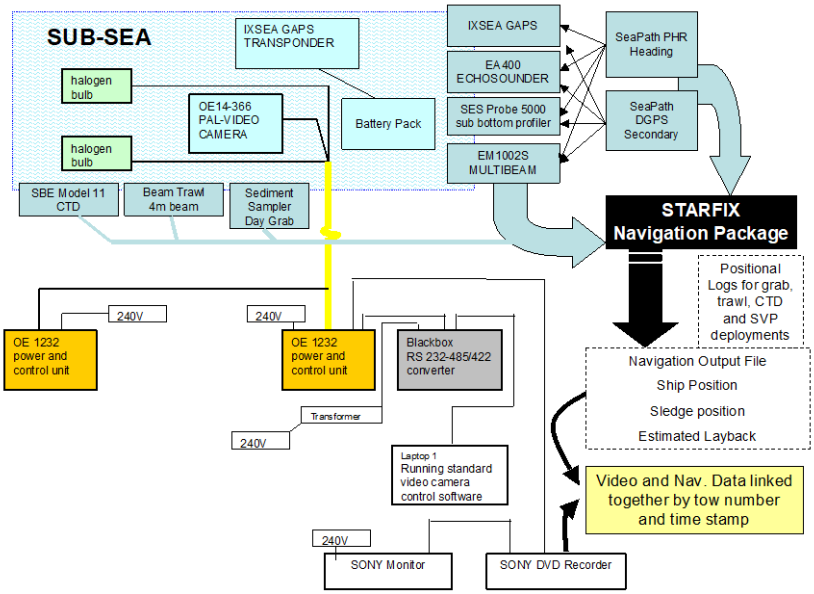


Figure 5.1.8.5. Schematic diagram of the sledge and traction on the sea bottom. Mechanism for acquiring process onboard. *Source: Marine Institute, Ireland.*

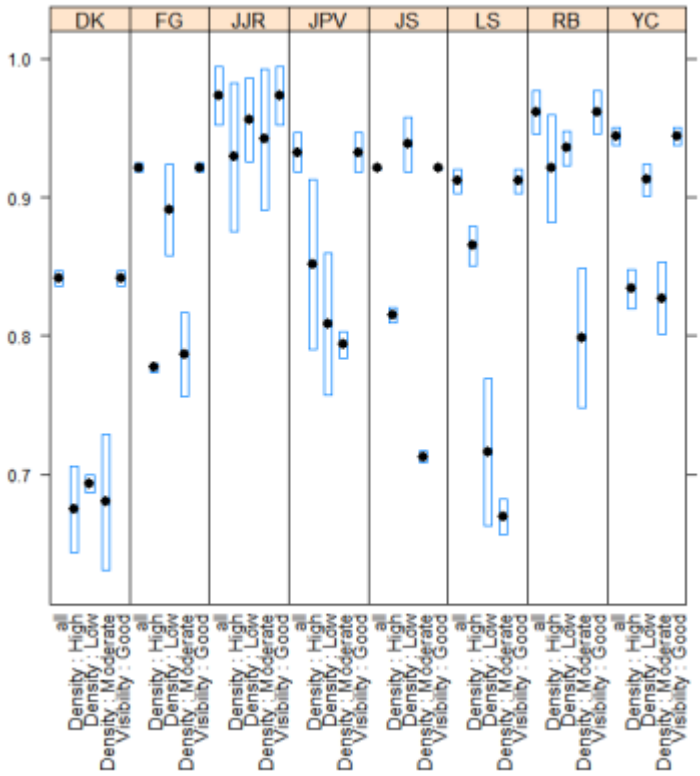


Figure 5.1.8.6. Conformity test CCC (reference footage: Smalls ground, FU22) . 2018's results.

3.2. Raising.

1. Raising to the five historical sedimentary strata (from the former trawl survey 2006-2013).

The whole area of the five historical strata was covered in 2014 although only 2/3 of the total number of stations were carried out in 2015. In the period 2016-2018, 100% of the Central Mud Bank was sampled (respectively 160, 94 and 148 validated stations; the 2017's lower sampling level is explained by the coverage of a wide area exceeding the actual Central Mud Bank of the Bay of Biscay (see above) whereas the additional sampling effort outside the edge in 2018 affected the sampling level in the 2016's benchmarked area in a lesser degree. Table 5.1.8.3 shows results of raising of burrow densities (/m²)[3] associated to their CVs by stratum for years 2014-2018. Results for 2018 show an increase by +18% compared to 2017 but a reduction of -7% compared to the 2016's values still remains.

[3] All rough results in § 3.2 are not yet corrected by the cumulative bias factor.

Table 5.1.8.3. Total number of burrows (10^6), densities/m² and CVs by spatial stratum and for the whole area. Years 2014-2018.

	2014 (156 stations)				*2015 (96 stations)*			
	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows
	0.442	**5164.53**	**5.82**		**0.386**	**4501.89**	**8.25**	
CB	0.317	802.68	15.68	15.54%	0.151	383.85	25.66	8.53%
CL	0.171	196.72	28.30	3.81%	0.306	352.28	18.57	7.83%
LI	0.354	1651.31	8.69	31.97%	0.320	1492.89	16.38	33.16%
VS	1.656	1048.72	11.05	20.31%	0.875	553.75	30.48	12.30%
VV	0.544	1465.10	13.19	28.37%	0.639	1719.13	10.99	38.19%

	2016 (160 stations)				*2017 (94 stations)*				*2018 (148 stations)*			
	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows
	0.386	**4505.52**	**7.86**			**3534.20**	**9.85**			**4172.82**	**8.44**	
CB	0.258	654.41	19.84	14.52%	0.152	384.49	20.10	10.88%	0.259	656.93	19.56	15.74%
CL	0.237	272.72	20.87	6.05%	0.262	302.03	14.76	8.55%	0.517	595.61	23.64	14.27%
LI	0.283	1319.12	13.86	29.28%	0.210	978.48	14.75	27.69%	0.228	1064.10	13.27	25.50%
VS	0.839	531.18	17.92	11.79%	1.147	726.44	27.94	20.55%	0.841	532.43	23.30	12.76%
VV	0.642	1728.09	14.52	38.35%	0.425	1142.76	19.82	32.33%	0.492	1323.75	17.30	31.72%

2. Raising to the restricted area sampled in 2015.

Comparisons of burrows densities are carried out by restricting the sampled area for 2014 and 2016-2018 to that covered in 2015. The basic condition of the stratified design is respected as all five sedimentary strata were sampled: although, the total surveyed area was reduced (7935 km² instead of 11676 km² of the five historical sedimentary strata) (table 4).

Table 5.1.8.4. Total number of burrows (10^6), densities/m² and CVs by spatial stratum and for the whole area. Years 2014-2018 after restriction to the area sampled in 2015 (7935 km² instead of 11676 km²).

	2014 (109 stations)				*2015 (96 stations)*			
	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows
	0.417	**3305.64**	**7.91**		**0.396**	**3138.42**	**7.85**	
CB	0.265	432.86	19.23	13.09%	0.151	247.63	25.66	7.89%
CL	0.171	196.49	28.30	5.94%	0.306	351.86	18.57	11.21%
LI	0.340	899.35	12.88	27.21%	0.320	847.72	16.38	27.01%
VS	1.656	665.91	11.05	20.14%	0.875	351.61	30.48	11.20%
VV	0.530	1111.04	17.90	33.61%	0.639	1339.59	10.99	42.68%

	2016 (102 stations)				*2017 (56 stations)*				*2018 (97 stations)*			
	nb/m²	total burrows	CV (%)		nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows
	0.412	**3266.09**	**9.98**		**0.364**	**2891.18**	**11.76**		**0.377**	**2992.53**	**8.01**	
CB	0.251	410.92	27.44	12.58%	0.211	345.51	21.29	11.95%	0.259	423.80	18.46	14.16%
CL	0.237	272.40	20.87	8.34%	0.262	301.67	14.76	10.43%	0.517	594.91	23.64	19.88%
LI	0.260	688.59	21.35	21.08%	0.271	717.67	21.84	24.82%	0.228	604.24	7.99	20.19%
VS	1.058	425.20	16.20	13.02%	1.403	564.02	28.30	19.51%	0.841	338.08	14.73	11.30%
VV	0.700	1468.99	17.20	44.98%	0.459	962.30	25.05	33.28%	0.492	1031.50	15.86	34.47%

As for the comparison on the five strata, density of burrows is characterized by a downward trend between 2016 and 2017 although in lesser degree (-11%) and a very slight increase afterwards (+4%).

3. Raising including the rough sea bottom.

The favourable weather conditions in spring 2016-2018 allowed to cover a supplementary area assumed to not be trawled as occupied by rough ground (Table 5.1.8.5). This additional stratum concentrating a moderate fishing pressure level as illustrated by VMS data were included in the five strata considered since the former trawl survey 2006-2013.

Table 55.1.8.. Total number of burrows (10^6), densities/m² and CVs by spatial stratum and for the whole area. Years 2016 and 2018 after including rough sea bottom contained in the outline of the Central Mud Bank (16164 km² instead of 11676 km² for the five sedimentary strata *sensu stricto*).

	2016 (196 stations)				*2017 (124 stations)*				*2018 (184 stations)*				
	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows	% surf
	0.320	**5167.67**	**7.84**		**0.259**	**4181.95**	**9.87**			**4696.84**	**8.30**		
CB	0.258	654.41	19.84	12.66%	0.152	384.49	20.10	9.19%	0.259	656.93	19.56	13.99%	15.69%
CL	0.237	272.72	20.87	5.28%	0.262	302.03	14.76	7.22%	0.517	595.61	23.64	12.68%	7.13%
LI	0.283	1319.12	13.86	25.53%	0.210	978.48	14.75	23.40%	0.228	1064.10	13.27	22.66%	28.85%
VS	0.839	531.18	17.92	10.28%	1.147	726.44	27.94	17.37%	0.841	532.43	23.30	11.34%	3.92%
VV	0.642	1728.09	14.52	33.44%	0.425	1142.76	19.82	27.33%	0.492	1323.75	17.30	28.18%	16.65%
RO	0.148	662.15	29.61	12.81%	0.144	647.75	34.23	15.49%	0.117	524.02	31.79	11.16%	27.76%

As for the other raising options, the number of burrows seems to have steeply declined between 2016 and 2017 (-19%) but an increase by +12% occurred in 2018. Anyway, for any year the two more compact muddy strata (VS and VV) corresponding to less than 20% of the overall surface concentrate around 40-45% of the total number of burrows.

4. 2018's raising including additional surface outside the 2016's benchmarked area.

Explorations performed in 2018 involved not only in the 16164 km² surface investigated since 2016 but also in an ancillary area exceeding the Central Mud Bank outline (≈2200 km²; Figure 4). Results are provided by Table 6.

Table 5.1.8.6. Total number of burrows (10^6), densities/m² and CVs by spatial stratum and for the whole area. Year 2018 according to two options: (1) surface of the 2016's benchmarked area (16164 km²); (2) surface including the additional one outside the outline of the stock limits (18360 km²).

	2018 (184 stations) 16164 km²				*2018 (215 stations) 18360 km²*			
	nb/m²	total burrows	CV (%)	% burrows	nb/m²	total burrows	CV (%)	% burrows
	0.291	**4696.84**	**8.30**		**0.259**	**4727.40**	**8.37**	
CB	0.259	656.93	19.56	13.99%	0.152	704.60	18.87	14.90%
CL	0.517	595.61	23.64	12.68%	0.262	614.08	23.64	12.99%
LI	0.228	1064.10	13.27	22.66%	0.210	1057.38	13.54	22.37%
VS	0.841	532.43	23.30	11.34%	1.147	482.82	28.20	10.21%
VV	0.492	1323.75	17.30	28.18%	0.425	1354.15	17.30	28.64%
RO	0.117	524.02	31.79	11.16%	0.144	514.36	30.14	10.88%

The additional area of 2200 km² does not contribute at all in the overall improve for estimates on the number of burrows. 14% of supplementary sampled surface provides an insignificant increase of less than 1% for burrows. It seems pertinent to limit further investigations on the standard area of 16164 km².

For any raising option, the 2018's UWTV survey provided indices upwards the 2017's ones although below those obtained in 2016.

3.3. Correction factors.

Edge effect: the edge effect calculated on 2014's data are represented by a corrective coefficient of 1.15 and it is associated to a low uncertainty (CV=11%). This value is still used for 2016-2018's data.

Detection: a very good visibility characterized footage during the four UWTV years (*e.g.* in 2014, 946 minutes of reading on 1095, *i.e.* 86%, have very high quality of image) and a correction factor of 0.94 is retained.

Species identification: The coexistence between Norway lobsters (*Nephrops norvegicus*) and squat lobsters (*Munida sp.*) and a certain capacity of the second species to colonize *Nephrops* burrows affect the correction factor of the "species identification", and is monitored each year (see section 5.5.1. for details).

The combination of the correction factors above provides a cumulative bias coefficient of 1.24.

The advice 2019 for the stock was performed on the basis of the 2018's UWTV survey results corrected by the cumulative bias coefficient combined with the harvest rate for the year 2017 (LFDs and mean weights for landings and discards, discard survival rate fixed at 30%) (Table 5.1.8.7).

Table 5.1.8.7. Catch option table for the FU23-24 *Nephrops* including information from the 2018's UWTV survey.

Catch scenarios

Table 2 Norway lobster in divisions 8.a and 8.b, functional units 23–24. The basis for the catch scenarios.

Variable	Value	Source	Notes
Stock abundance (2019)	3788 million individuals	ICES (2018)	UWTV survey 2018 (used as abundance estimate for 2019).
Mean weight in landings	24.94 g	ICES (2018)	Average 2015–2017.
Mean weight in discards	12.05 g	ICES (2018)	Average 2015–2017.
Discard rate	55.6%	ICES (2018)	Average 2015–2017 (by number). Calculated as total discards divided by landings + total discards.
Discard survival rate	30%	ICES (2018)	Only applies in scenarios where discarding is assumed to continue.
Dead discard rate	46.7%	ICES (2018)	Average 2015–2017 (by number). Calculated as dead discards divided by dead removals (landings + dead discards). Only applies in scenarios where discarding is assumed to continue.

Table 3 Norway lobster in divisions 8.a and 8.b, functional units 23–24.

a) Catch options for 2019 assuming zero discards.

Basis	Total catches	Wanted catches*	Unwanted catches*	Harvest rate**
ICES advice basis				
MSY approach (F_{MSY} harvest rate)	5184	3231	1953	7.70%
Other options				
F_{2017}	5668	3533	2135	8.40%

* "Wanted" and "unwanted" catch are used to describe *Nephrops* that would be landed and discarded in the absence of the EU landing obligation, based on the average estimated discard rates for 2015–2017.
** Calculated for dead removals and applied to total catch.

b) Catch options for 2019 assuming discarding continues at the recent average rate.

Basis	Total catches	Dead removals	Landings	Dead discards	Surviving discards	Harvest rate*
	L+DD+SD	L+DD	L	DD	SD	for L+DD
ICES advice basis						
MSY approach; F_{MSY}	6221	5518	3878	1641	703	7.70%
Other options						
F_{2017}	6802	6033	4240	1794	769	8.40%

* Calculated for dead removals and applied to total catch.

5.1.1 Iceland

(Jónas Jónasson)

FU1 (Off South Iceland)

The third UWTV survey on *Nephrops* ground in Iceland was carried out by the Marine and Freshwater Research Institute (MFRI) between 11th – 20rd of June 2018. The survey took place on RV Bjarni Sæmundsson. Like previous two surveys it covered all known *Nephrops* ground in FU1.

Area definition was based on avialable AIS data (2008 – 2017). Vessel fishing with *Nephrops* trawl and at towing speed (1 – 4 nm) were summarizd on grid with a resolution of 800 m. A minimum of five trawling ocurrance was choosen as a threshold value for each area within the grid. Further the minimum size of each area was set as 4 km^2. In total 12 distinct fishing grounds were identified and further summerized to 9 areas (Fig 5.1.9.1). In total the *Nephrops* grounds in FU1 were estimated to be 6353 km^2 compared to 5989 km^2 based on VMS data from 2008-2016. The increase between years is mostly due to new fishing areas being exploited in southwestern part of the grounds.

Stations were laid out in similar mannar as previous two years on a randomized fixed square grid with around 4.5 nautical miles between points, with in total of 94 stations completed. The depth of stations ranged from 106 to 280 m. The sledge was equipped with an HD camera, mounting at 45° and lasers 100 cm apart. The tow speed ranged between 0.5–1.5 knots and cable was payed in or out to obtain the best possible footage, but 10 minutes were recorded on each station. Vessel position (DGPS) and odometer on the sledge was used to estimate the distance overground (DOG).

All burrow system were timestamped by two readers, following recommendation from WKNEPH (November 2016) where reference footage of the FU1 ground was established. In case of disagreement, the footage was reviewed again by both readers and agreed on or left to third counter.

The mean burrow density (adjusted to account for bias factors) was 0.07 burrows per m^2 with CV of 3.7% (Fig 5.1.9.1). The total number of burrows in 2018 was 462 million (adjusted values). The total number of burrows in 2017 was slightly higher or 540 million, which was only marginally different from the estimate of the first survey counducted in 2016, when the total number of burrows was 542 million (Fig 5.1.9.2).

From the UWTV footage, the occurrence of trawl marks, seapens, fish and other species were also noted. Trawl marks in 2016 were noted at 71% of the stations surveyed, with an average of 2.5 marks per station. In the 2017 survey, trawl marks were noted at 81% of station with on average 7.2 trawl marks per station. Trawl marks have not yet been analysed for 2018. Two seapens species, *Virgilaria mirabilis* and *Pennatula spp.*, have been identified from the video. *Virgilaria* was present on 88% of station in 2016 and 67% station in 2017. *Pennatula* was present on 14% of station in 2016 and 10 % in 2017. Seapens have not yet been counted from the 2018 survey.

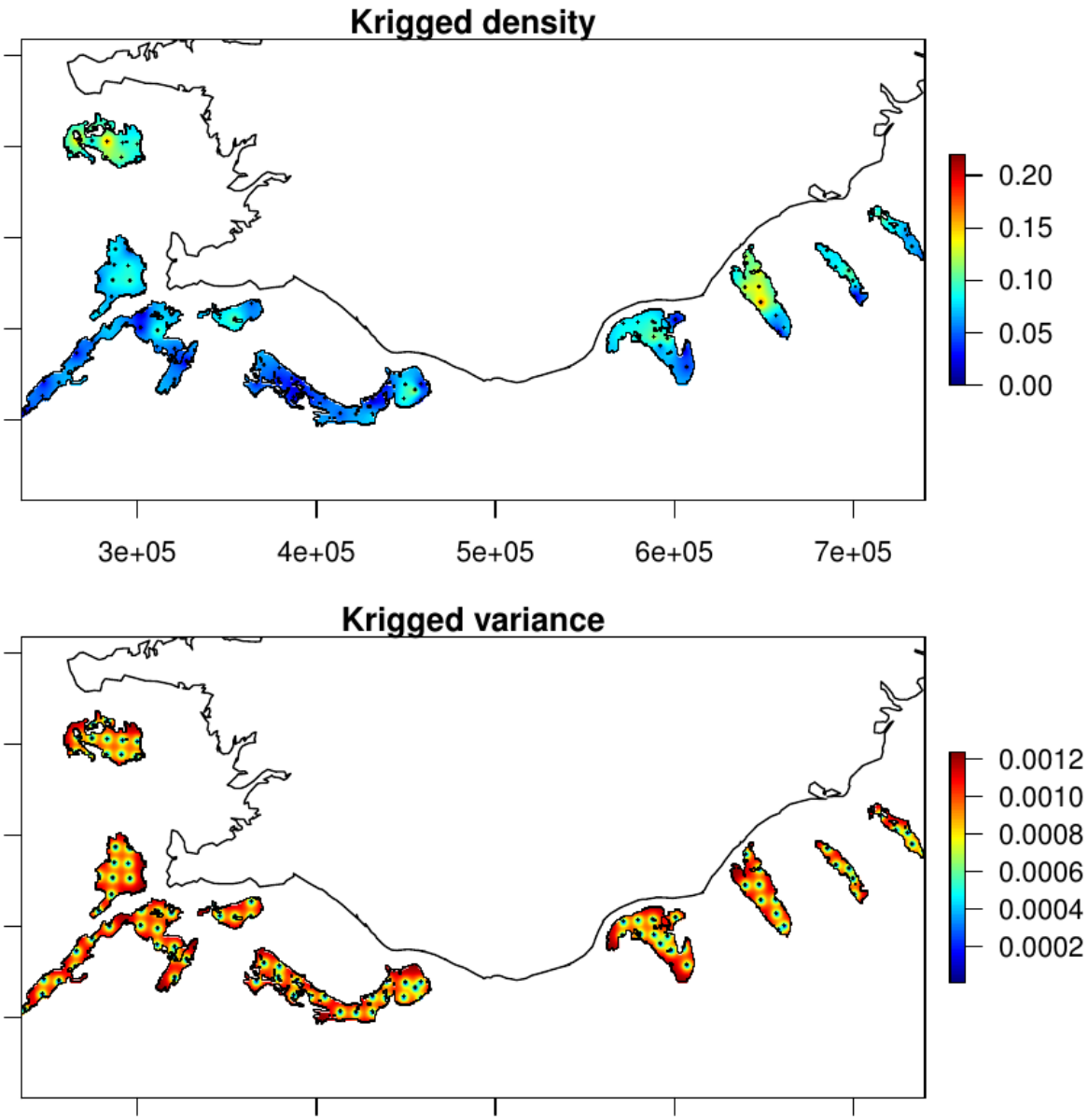


Fig 5.1.9.1. FU1 grounds: Contour plots of the krigged density estimates (above) and krigged variance (below), from the 2018 survey.

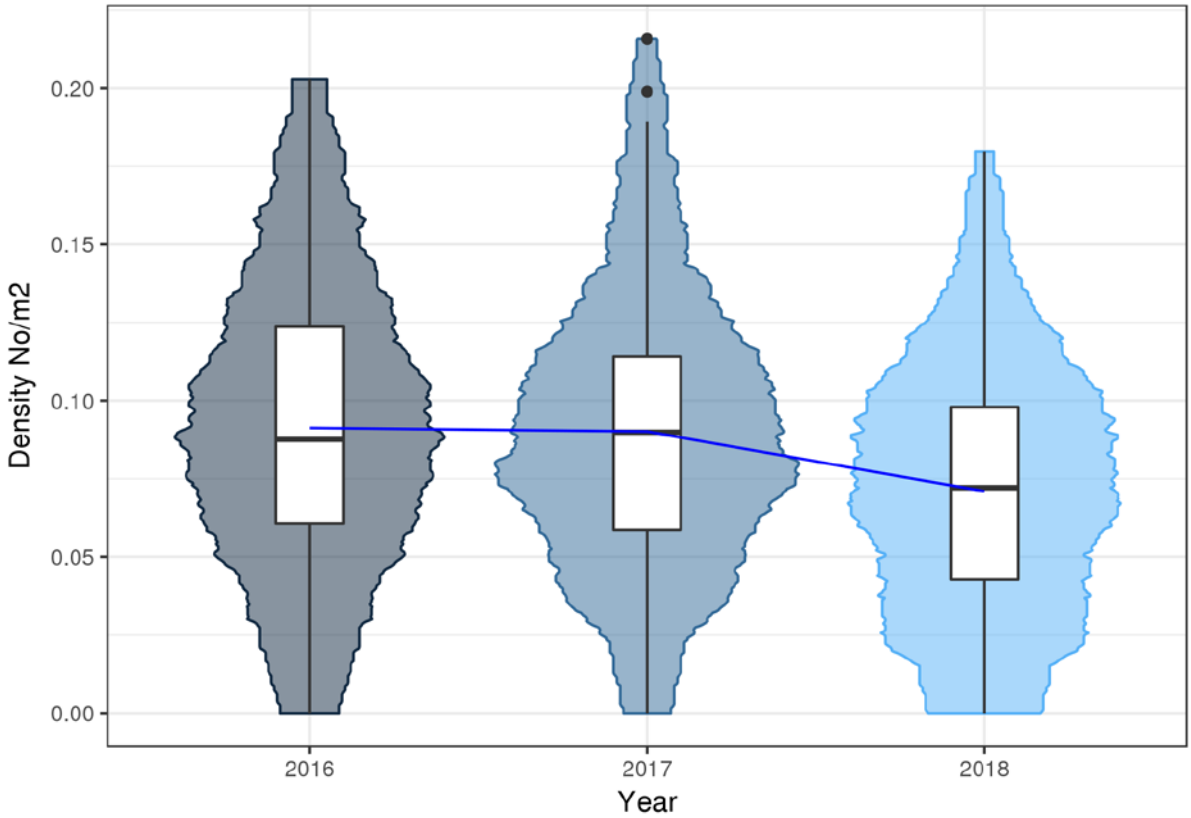


Fig 5.1.9.2. FU1 Iceland: Violin and box plot of adjusted burrow density distributions by year from 2016 - 2018. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

5.1.2 Portugal

(Christina Silva)

FU 28-29: SW and S Portugal

Definition of fishing grounds

VMS fishing records from the period 1999-2016, linked with logbook data, were used to define the crustacean fishing grounds (Figure 5.1.10.1).

Although Norway lobster and rose shrimp distributions overlap in some areas and depths, the main fishing grounds for Norway lobster are Sines in FU 28 and Olhão, Beirinha and ZEE in FU 29, while for Rose Shrimp the most important are Arrifana in FU 28 and Sagres-Portimão ("sagpor") and Olhão-Portimão ("olhpor") in FU 29. Rose shrimp is caught in areas shallower than 500 m and *Nephrops* in areas in the range 200-750 m. Sediment samples collected in all area indicate that Norway lobster has preference for substrate composed by more than 80% of silt and clay.

The delimitation of the fishing grounds was used to better define the survey area, sampling strata and design.

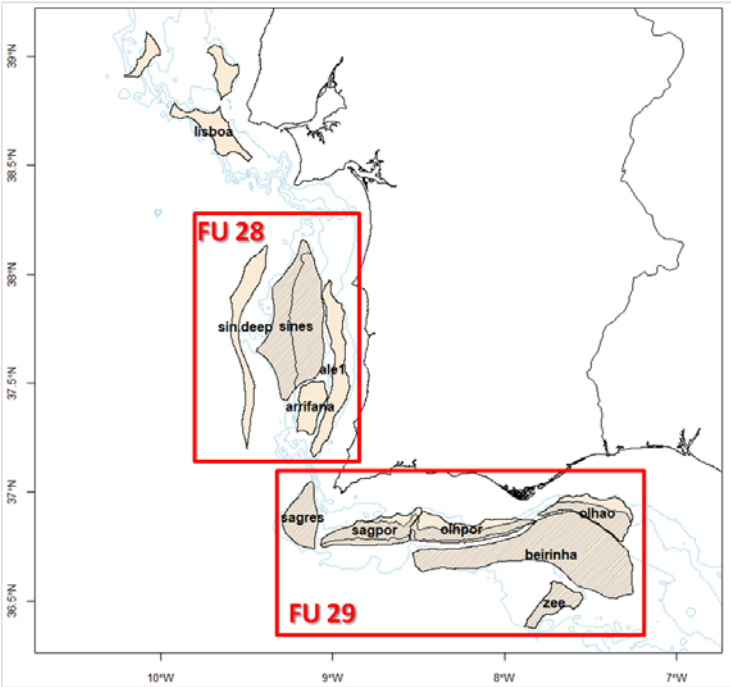


Figure 5.1.10.1. Crustacean fishing grounds based on VMS trawl data. The dashed areas (> 200 m) are the main fishing areas for Nephrops.

The trawl survey

The trawl survey was conducted in July-August 2018 with the RV NORUEGA covering Functional Units 28 and 29 with 59 valid hauls (13 in FU 28 and 46 in FU29). As in previous years, the sampling grid included 78 rectangles, with 33 squared nautical miles each (see Annex 8.3).

The grid was designed to cover the main crustacean fishing grounds within the range of 200-750 m. The substrate in these grounds is characterized by muddy sediments composed by different percentages of silt and clay.

One station is carried out within each rectangle. The hauls were carried out during daytime with a speed of 3 knots and have 30 minutes of duration. Although directed at the crustacean species (Norway lobster, rose shrimp and red and blue shrimp), data from all other taxa and species are also collected, as well as on marine litter.

The survey is generally carried out in June-July, during *Nephrops* main fishing season, when males and females are available to the gear and most of females are in prespawning state, with ripe ovaries. The trawl survey provides indices of relative abundance and biomass of *Nephrops* stocks, which have been used in the stock trends assessment. In 2018, the survey was conducted almost at the end of the fishing season (July 26 – August 13), when spawning and egg-bearing period starts and the female availability to fishing also decreases.

Figure 5.1.10.2 shows the spatial distribution of the biomass index in the most recent years.

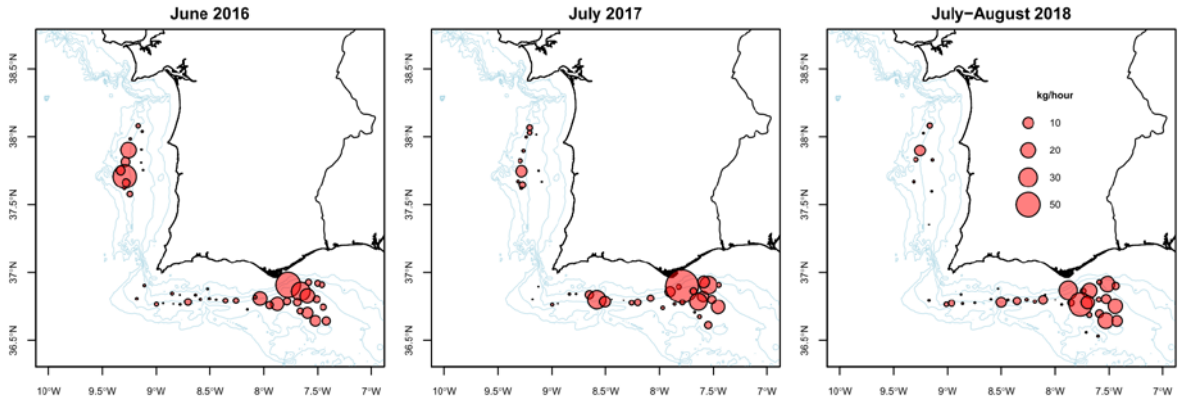


Figure 5.1.10.2. Spatial distribution of Norway lobster biomass index in 2016-2018.

The survey mean abundance index is estimated using the area stratification in fishing grounds and depth intervals as defined above.

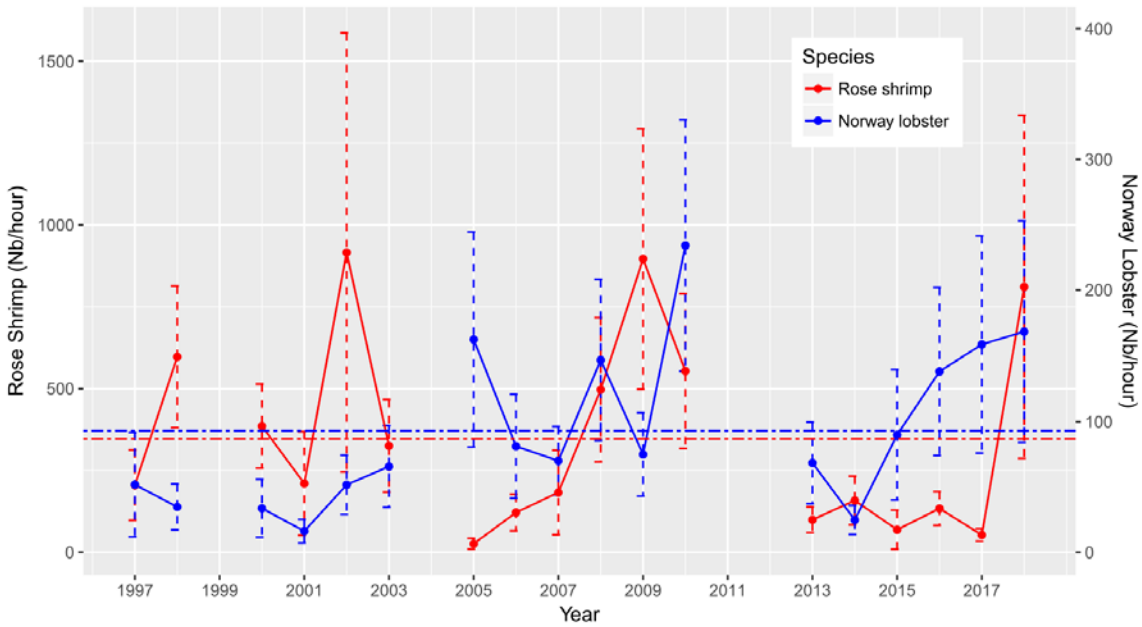


Figure 5.1.10.3. Abundance index (number/hour) of rose shrimp and Norway lobster with 95% CI in the period 1997-2018 and the long term average abundance for both species (horizontal lines).

Figure 5.1.10.3 shows the abundance index time-series for Norway lobster in FUs 28-29, as well as for rose shrimp, the other target species in these grounds. In 2005-2018, after a major change in the sampling design (definition of the sampling grid, reduction of haul duration and increase of the number of hauls), the CV has varied in the range of 19-28%. In general, periods of high abundance of rose shrimp alternate with periods of high abundance of Norway lobster. This pattern has been observed either in surveys or in the fishery.

No estimates are presented for 1999, 2004, 2011 and 2012. In 1999 and 2004, the surveys were carried out with different vessels, only covering FU 29 in 1999 and having some problems with the gear in 2004.

In 2011, due to engine failure the survey did not cover the whole area. In 2012, the vessel was under repair and no survey was conducted.

Figure 5.1.10.4 shows the population length structure by area and depth of 2018 survey. In general, the mean length is larger in FU28 than in FU29.

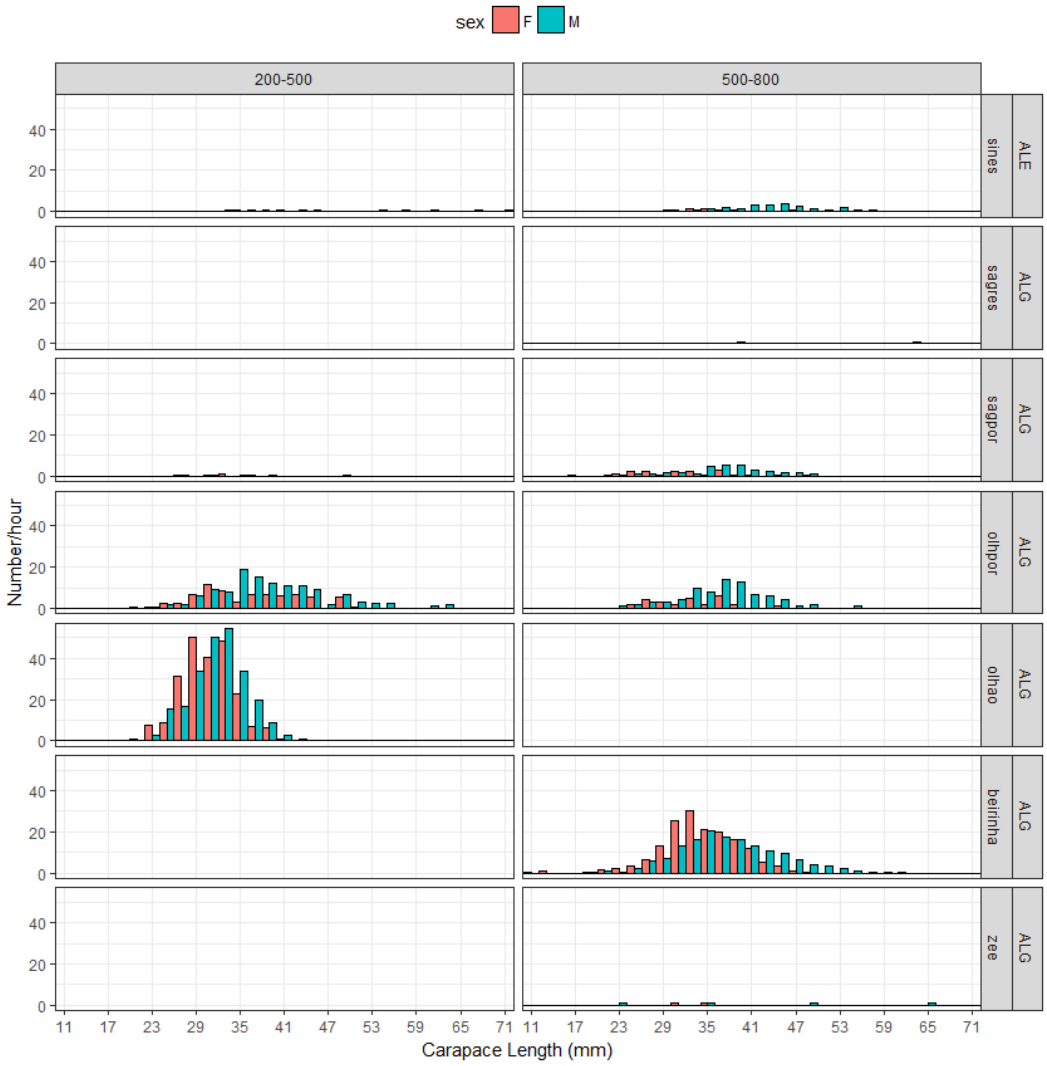
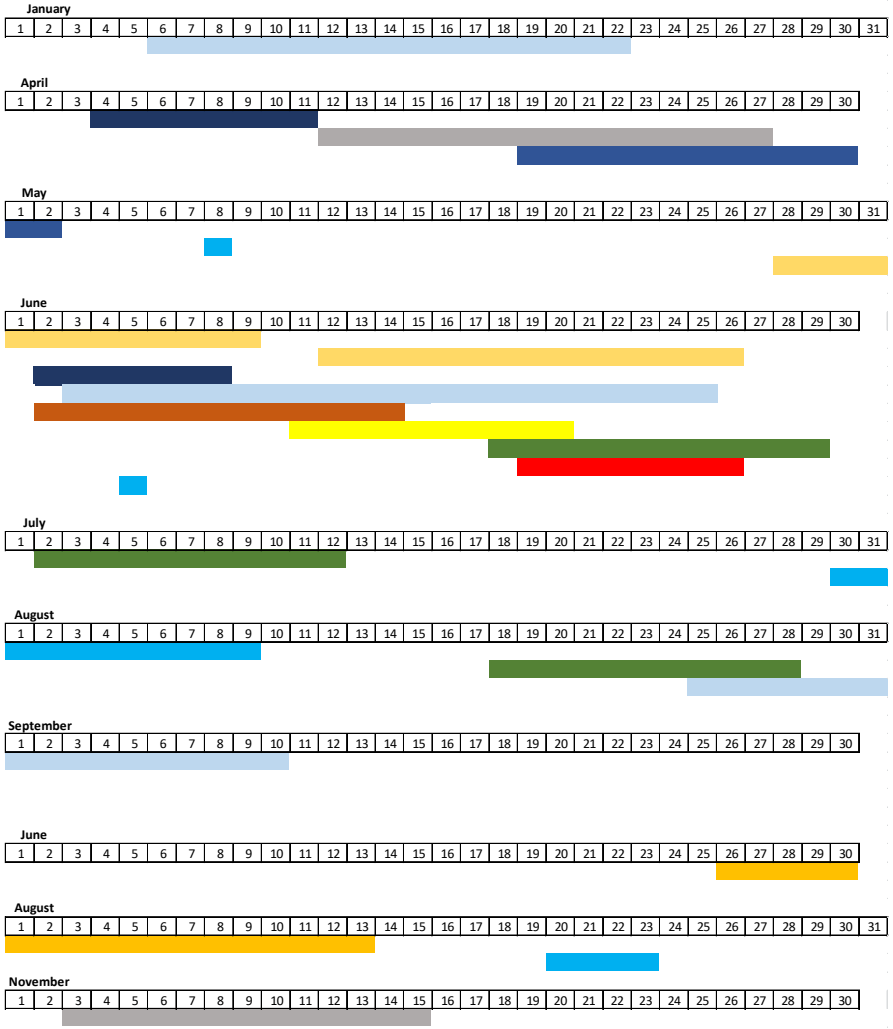


Figure 5.1.10.4. Length composition (in number/hour) of Norway lobster of males (M) and females (F) by zone and depth.

5.1.11 Overview on the timing of *Nephrops* surveys conducted in 2018 and planned for 2019

2018

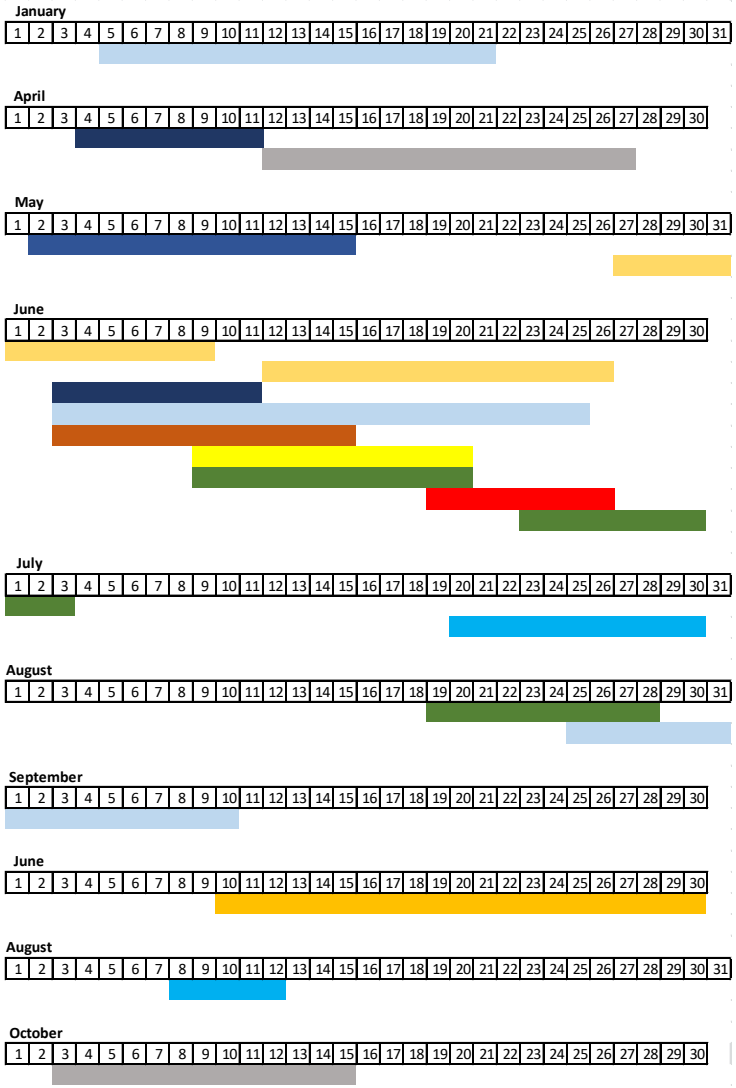
Institute	Survey Type	Survey Area	Ship
MSS-Scotland	UWTV	West Coast Sealochs	Alba na Mara
DTUAqua-Denmark	UWTV	FU3&4	Havfisken
Italy/Croatia*	UWTV	Pomo Pit - GSA17	G.Dallaporta
Ifremer-Lorient	UWTV	FU23-24	Celtic Voyager
Ifremer-Lorient	UWTV	FU23-24	Celtic Voyager
AFBI-Belfast	UWTV	Strangford Lough	Corystes
SLU-Sweden	UWTV	FU3&4	Havfisken
SLU-Sweden	UWTV	FU3&4	Havfisken
SLU-Sweden	UWTV	FU3&4	Asterix
DTUAqua-Denmark	UWTV	FU33	Havfisken
MSS-Scotland	UWTV	FU7, 11-13, 34, 10	Scotia
IEO-Cadiz	UWTV	FU30	Angeles Alvarino
HAFRO-Iceland	UWTV	FU1	Bjarni Sómundsson
MI-Ireland	UWTV	FU16, FU17	Celtic Voyager
CEFAS-UKE&W	UWTV	FU6	Endeavour
AFBI-Belfast	UWTV	Strangford Lough	Corystes
MI-Ireland	UWTV	FU19, FU20-21, FU22	Celtic Voyager
AFBI-Belfast	UWTV	FU14, FU15	Corystes
AFBI-Belfast	UWTV	FU14, FU15	Corystes
MI-Ireland	UWTV	FU19, FU20-21, FU22	Celtic Voyager
MSS-Scotland	UWTV	FU8, FU9	Alba na Mara
MSS-Scotland	UWTV	FU8, FU9	Alba na Mara
IPMA-Portugal	Trawl	FU28-FU29	Noruega
IPMA-Portugal	Trawl	FU28-FU29	Noruega
AFBI-Belfast	Trawl	FU14, FU15	Corystes
Italy/Croatia	Trawl	Pomo Pit - GSA17	G.Dallaporta



* was not carried out due to unavailability of the R/V G. Dallaporta (works to be done on the ship not foreseen before)

2019

Institute	Survey Type	Survey Area	Ship
MSS-Scotland*	UWTV	West Coast Sealochs	Alba na Mara
DTUAqua-Denmark*	UWTV	FU3&4	Havfisken
Italy/Croatia*	UWTV	Pomo Pit - GSA17	G.Dallaporta
Ifremer-Lorient	UWTV	FU23-24	Celtic Voyager
SLU-Sweden*	UWTV	FU3&4	Havfisken
SLU-Sweden*	UWTV	FU3&4	Havfisken
SLU-Sweden*	UWTV	FU3&4	Asterix
DTUAqua-Denmark*	UWTV	FU33	Havfisken
MSS-Scotland*	UWTV	FU7, 11-13, 34, 10	Scotia
IEO-Cadiz	UWTV	FU30	Angeles Alvarino
HAFRO-Iceland	UWTV	FU1	Bjarni Sómundsson
MI-Ireland	UWTV	FU16, FU17	Celtic Voyager
CEFAS-UKE&W*	UWTV	FU6	Endeavour
MI-Ireland	UWTV	FU19, FU20-21, FU22	Celtic Voyager
MI-Ireland	UWTV	FU19, FU20-21, FU22	Celtic Voyager
AFBI-Belfast	UWTV	FU14, FU15	Corystes
MI-Ireland	UWTV	FU19, FU20-21, FU22	Celtic Voyager
MSS-Scotland*	UWTV	FU8, FU9	Alba na Mara
MSS-Scotland*	UWTV	FU8, FU9	Alba na Mara
IPMA-Portugal*	Trawl	FU28-FU29	Noruega
AFBI-Belfast	Trawl	FU14, FU15	Corystes
Italy/Croatia*	Trawl	Pomo Pit - GSA17	G.Dallaporta



* dates provisional at time of reporting check with institutes for confirmations in 2019

5.1.12 Outcome of WKNEPS on *Nephrops* burrow counting in 2018

(Jennifer Doyle, Adrian Weetman)

WGNEPS considered and discussed the outcome of the 2018 burrow counting workshop in particular in respect to final draft of the SISP. Details will be given in the workshop report (ICES, in prep.).

5.2 ToR c. To review video enhancement, video mosaicking, automatic burrow detection and other new technological developments.

5.2.1 Mosaicking and annotated footages

An updated version of a software package to process bottom video recordings from *Nephrops* cruises developed by Bo Lundgren (DTU Aqua) was distributed to the participants of the meeting in 2017. The software package allows transformation of the videos into mosaic and live annotation of burrow counts (ICES, 2017c). However, the software was less often used than initially expected because the data formats differed between the national labs. Mosaicking software has recently also been developed using footages from the Irish UWTV surveys (Corrigan et al. 2018). However, identifying and annotating burrows using mosaicking software is more time consuming than applying the standard procedure for counting. Nonetheless, it is still recommended to use such software for analysing at least reference footages because this would make an identification of differences between readers more easy.

5.2.2 *Nephrops norvegicus* detection and classification from underwater videos using Deep Neural Network

(Atif Naseer)

1. Introduction

Spanish Institute of Oceanography has a research group working on *Nephrops norvegicus* identification and counting. They are conducting the survey on yearly basis. The survey is conducted through special equipment and underwater camera. A 10-12 minutes video was made on each point of interest and the whole survey has more than 20-30 points of interest yearly. Currently they are counting the holes manually by reviewing the video frame by frame in multiple parallel session and conclude the results on consensus of all members. This exercise cost lot of resources in terms of time, human and cost. There is no system available that can help them in solving their current problem.

2. Problem Statement

During the past many years this specie is counted manually from underwater videos which is very tedious and time-consuming task. These species are usually lived under the sand. To identify this specie in underwater, one need to identify the pattern of *Nephrops* burrows on the seabed. These burrow complexes are very specific for this specie.

Some of the major research problems from the engineering point of view are:

- To understand the dataset and its limitations.
- To identify the mechanism for preprocessing of underwater videos to improve the quality.
- To mark the ground-truth image annotation on dataset.

- To validate the dataset.
- To explore the state-of-the-art deep learning based underwater object detection and recognition algorithm.
- To identify the pattern of burrows and classify between different types of burrows.
- To propose a deep learning algorithm to automatically detect and classify the pattern of holes and provide the assessment of the species.

3. Proposed Solution and Objective

To solve the above-mentioned problems, we are proposing a deep learning algorithm to automatically detect and classify the pattern of holes and provide the assessment of the specie.

Following are the phases that are required to achieve the above-mentioned objectives. These phases are:

3.1. Data Preparation

The data preparation is the most important phase of the project. This phase is required to prepare the data for building a model. The data are available in many forms like avi, mp4, analog, and full HD. The proposed deep learning model requires homogeneous data for training. Hence, we are applying following steps in this phase.

3.1.1. Preprocessing of Data:

The available data require preprocessing due to its heterogeneous nature. The quality of videos will be improved by improving lightening effects, noise mitigation, color compensation and image contrast enhancement.

3.1.2. Ground-truth Image Annotation:

The next major step in this phase is to annotate the images to build a comprehensive dataset. The image annotation is tedious and time-consuming job.

Initially, we started to annotate the image by writing a program to automatically annotate the burrows. As this initial version is developed without any learning algorithm so, it has lot of problems like detection of wrong burrows and undetected burrows.

So, we build a Manual Image Annotation Tool. This tool allows the user to annotate every unique frame of video. In this tool user has the control to annotate any burrow based on his/her understanding. The outputs of this tool are the annotated images and their data in the form of coordinates and measurements. Some of the problems of the manual annotation tool are (i) unnecessary burrow detection due to lack of domain knowledge, (ii) the tool is annotating each unique frame of the video.

The next step is to build a semi-auto annotation tool. Currently this tool is under construction. This tool will initially annotate the frame automatically. It will provide flexibility to user to add/remove any annotated burrow. This exercise is time consuming but necessary for building an accurate model. This tool will help us in collecting a good dataset for building a deep learning model.

3.1.3. Validation of Annotation

The annotated images should be verified from the experts. The validation of annotations is an important step before building a model. If we provide wrong annotated data to train the model than the model will not detect and count the *Nephrops* burrows accurately.

3.2. Model Training

In this phase a Deep Neural Network for underwater video analysis will be developed. To build a model the annotated images of *Nephrops* burrows are required. Once the model is ready than it will be trained using more annotated images. Initially 30% of the available data will be used for training.

3.3. Model Testing

When the model will be ready it will be tested using remaining 70% of the data. This model training and testing is an iterative process and will be improved in every iteration.

3.4. Proposed System

The last step of the project is to build a User-friendly software to automatically detect, classify and count *Nephrops* burrows. The system will be based on state-of-the-art Deep Neural Algorithm.

4. Challenges

Some of the major challenges that I am facing in this project are:

- I am not an expert in burrows detection so, I wrongly annotate lot of burrows.
- Some burrows are complex in nature so, need experts opinion in this regard.
- Some training sessions are required with experts.
- Due to complex nature of problem, need to re-train the model in multiple iterations.
- Need lot of time in manual annotation.

5.3 ToR e. Discuss the utility of UWTV and trawl *Nephrops* surveys as platforms for the collection of data for OSPAR and MFSD indicators.

Several teams involved in *Nephrops* UWTV surveys provide video recording from these surveys to other laboratories e.g. for studying distribution of sea pens or other ecological valuable information (see section 5.1.). However, usually no feedback on the results is received and WGNEPS will therefore contact these laboratories to report on their experience with the *Nephrops* UWTV and present their results during a future WGNEPS meeting.

5.4 ToR f. Develop an international database which will hold burrow counts, ground shape files and other data associated with UWTV surveys.

The UWTV *Nephrops* surveys provide stock abundance data for direct use in ICES stock assessments. In the majority of cases, data from these surveys are collated, stored and worked up locally by national institutes. Due to the significant number and importance of these surveys, interest in the topic and frequency of data requests from external par-

ties, ICES has identified the requirement for data from these surveys to be stored centrally on a database in the ICES Data Centre, in line with other surveys with a similar standing.

At WGNEPS 2016 the potential fields required in an ICES supported database were discussed at length. Discussions via Webex with ICES database designers were conducted during the 2016 meeting and this provided a clearer understanding of what was required from the group.

At WGNEPS 2017 a subgroup was formed to develop the database approach and following the meeting, a Skype conference call was conducted in December 2017. From this discussion further fields were suggested and an initial format was created. This draft proposal, consisting of five metadata tables, was circulated among the database development subgroup and other interested colleagues within WGNEPS, which provided feedback and further recommendations.

It was agreed at WGNEPS that to proceed with this ToR, that all feedback previously received from group members should be amalgamated and recirculate for review. The subject regarding the many regular requests for information on *Nephrops* functional units were also raised and the challenges experienced in trying to obtain this information. The group agreed that the ICES Data Centre's source information should be updated to include GIS layers containing data on the specific statistical rectangles for each functional unit and the polygons for each *Nephrops* UWTV survey area, addressing the need for accurate, relevant, centrally held, publicly available spatial information on *Nephrops* survey grounds without the need to wait for the database to go live.

5.5 ToR g. Review of existing datasets to evaluate possible factors affecting (i.e. currents, light, etc.) burrow emergence.

5.5.1 Coexistence and burrow emergence of Norway lobster (*Nephrops norwegicus*) and squat lobsters (*Munida sp.*) in the Gulf of Biscay

(Spyros Fifas)

The coexistence between Norway lobsters (*Nephrops norvegicus*) and squat lobsters (*Munida sp.*) and a certain capacity of the second species to colonize *Nephrops* burrows affect the correction factor of the "species identification". The interaction *Nephrops* and *Munida* is not relevant to many other *Nephrops* stocks already routinely video surveyed either because of the depth (Iberic stocks, bank of Porcupine) or due to the latitude as *Munida* is more southerly spread than *Nephrops* in the NW Atlantic waters.

Video on years 2014-2018 allows to investigate the basic differences of dial activities for both species: *Nephrops* is active during a more restrictive time interval within a day whereas the activity of *Munida* is more widely spread on 24 h (Figure 5.5.1.7 and 5.5.1.8). The intuitively expected case of *Nephrops* activity around dawn and dusk was observed on data collected in September 2014, May 2016 and May 2017, although 2015's data presented a different profile (see WGBIE 2017) and 2018's data showed no relevant pattern to be fitted (Figure 5.5.1.7). *Munida* showed wider profile of emergence with two close study cases of minimized activity near dawn and dusk (September 2014, May 2017); at the opposite, 2016's and 2018's observations do not correspond to the same scheme whereas 2015's data are not relevant (Figure 5.5.1.8). The observed active individuals fluctuated a lot: for *Nephrops* in the range 382-1369 (minimum in 2014, maximum in 2016) and for *Munida* in the range 151-2653 (minimum in 2018, maximum in 2014). It is noticeable that *Munida* was systematically represented by larger numbers

apart from 2018's survey. Combining those results on footage and trawling experimental catches (for years 2014 and 2015) on both species allow to propose species identification coefficient of 1.05, 1.10 or 1.15. The third value was retained by 2016's WKNEP benchmark for the stock.

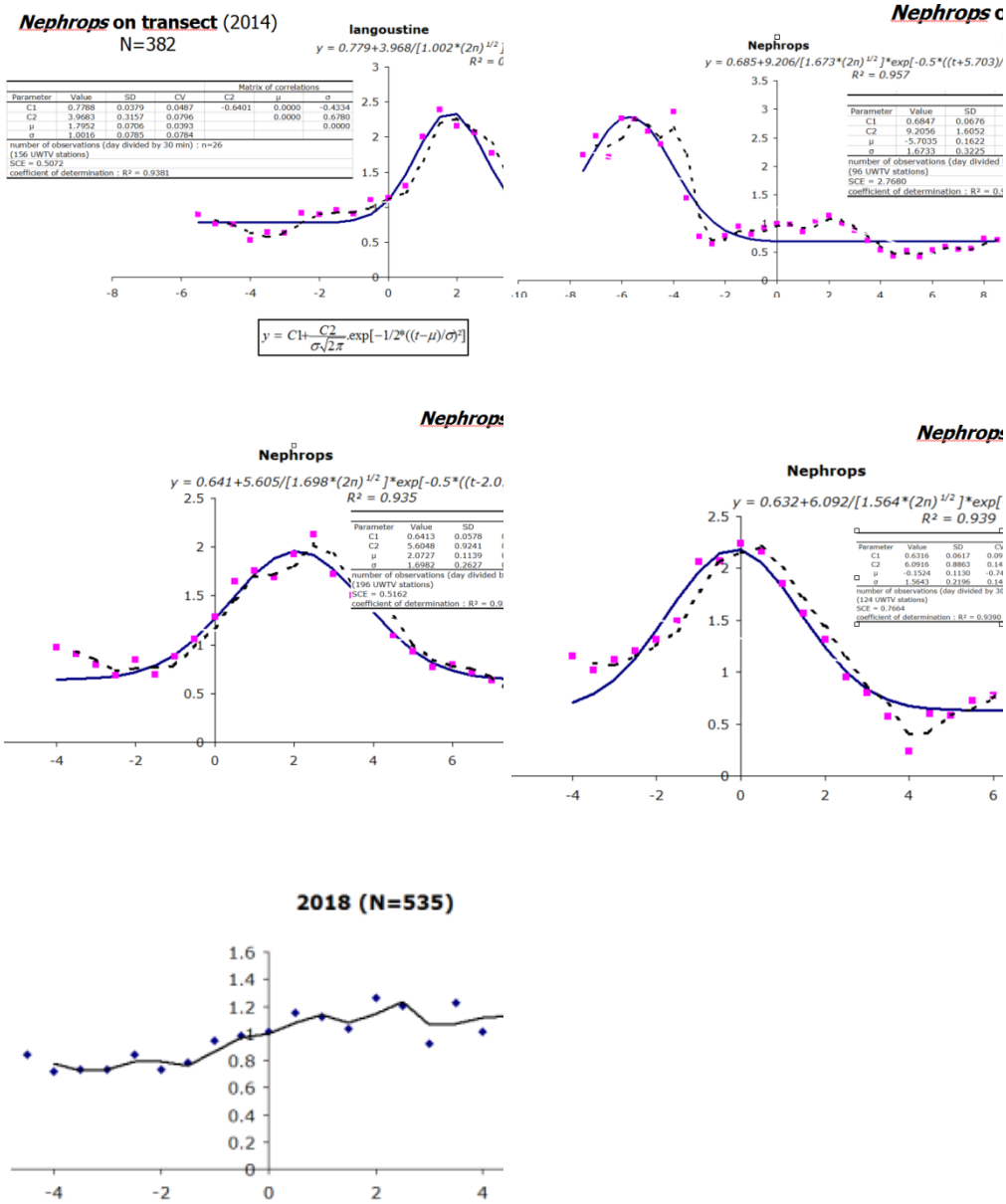


Figure 5.5.1.7. Relationship between standardized time of observation *vs.* sunrise/sunset and *Nephrops* activity for years 2014-2018. Abundance index per surface unit of video track *(broken curve: data smoothed by mobile average).*

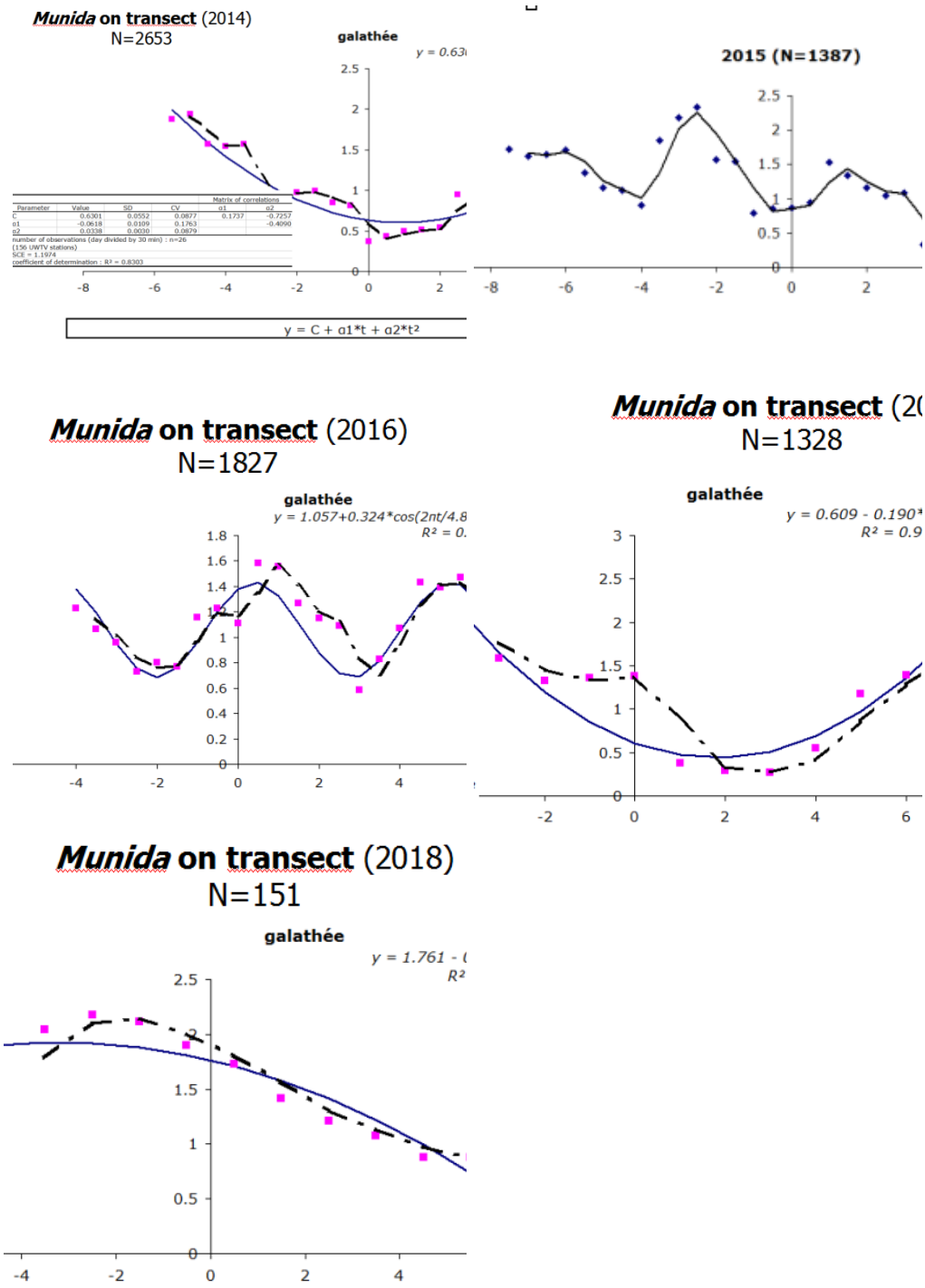


Figure 5.5.1.8. Relationship between standard time of observation vs. sunrise/sunset and Munida activity for years 2014-2018. Abundance index per surface unit of video track (broken curve: data smoothed by mobile average).

5.5.2 New monitoring technologies to produce ancillary data on Nephrops stock assessment

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In collaboration with

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Current stock assessment based on UWTV surveys counts of *Nephrop*s burrows (and thus inhabiting individuals) based on the peculiar morphological traits of these structures within the substrate. Three major uncertainties have been identified in this methodology: i. burrow occupancy which is currently assumed to be of one individual >17mm carapace length per identifiable burrow system; ii. burrow system size and the "edge effect" which could bias the estimates of effective area surveyed; iii. Burrow identification because other sympatric fish and decapod species construct tunnels with morphology similar to those of *Nephrops*. It is therefore of relevance to produce data on burrow emergence to validate or improve the assumptions made in the UWTV assessment methodology. New in situ technological applications should be used to monitor burrowing behavior producing data on the following key aspects: i. Burrow persistence related to the death and opportunistic occupation by other species; ii. Burrow emergence rhythms at different time-scales which oblige to perform surveys in specific time windows (tidal, day and seasons); iii. Emergence duration that varies according to the hunger state (predation-scavenging), predator presence (visual contact, odor plumes, noise) and intraspecific interactions (territoriality); and finally, iv. emergence range, identifying how many holes belong to a single animal.

Fixed-point cabled observatories provide highly-integrated biological and environmental data measurements that are continuous (i.e. benefitting from nearly unlimited power supply), and at very high frequencies, allowing species abundance estimates to be corrected by intrinsic species-specific biorhythmic fluctuations in response to environmental cycles. Different research activities are being performed in 2 key structure hubs of the European Multidisciplinary Seafloor and water column observations (EMSO) network: SmartBay (20 m depth, Galway, Ireland); OBSEA (20 m depth, Vilanova I la Gertru, Spain). Observatories cameras and new autonomous imaging devices, conceived for long lasting autonomous deployment (GUARD1/DeepEye) will be used for the time lapse monitoring the burrow emergence behavior in *N. norvegicus* (Figure 5.5.2.1). In order to do so, during the 2019, we will enforce a video-based evaluation of: i. the dynamic of burrow digging and maintenance by each individual; ii. the role of ecological (i.e. predators and preys) and the environmental (oceanography and meteorology with special focus on light) control in modulating individual variability of burrow emergence; iii. the role of social aggressive interactions in modulating emergence timing and duration of emergence in a group of neighbors; and finally, iv. The establishment of an automated video-imaging protocol to track animal movement and to identify social aggressive interactions occurrences. Video data will serve as cross validation for acoustic tagging procedures in a shallow water controlled environment prior

to final procedures of mooring deployment in the no take zone off Blanes/Palamós (Spain), at 350-400 m depth. These research activities will be conducted in February at OBSEA within the framework of the following projects:

1. Autonomous and cabled underwater sensor networks applied to remote monitoring of biological indicators (RESBIO; TEC2017-87861-R)
2. Marine no-take areas as a tool to recover iconic Mediterranean fisheries in decline: the case of *Nephrops norvegicus* (RESNEP; CTM2017-82991-C2-1-R)

Preliminary video data on animal burrow emergence are already under analysis from SmartBay videos obtained in the framework of the following TNA project: Automatic Data and Video Acquisition for uNderwater monitoring across Coastal obsErvatories (ADVANCE; H2020-INFRAIA-2014-2015 under the Grant Agreement no. 654410, JERICO-NEXT, as well as SmartBay Ireland /Marine Institute as the Facility Operator).

A.

B.

Figure 1. field of view of camera installed on SmartBay observatory depicting the burrow emergence activity of 2 animals belonging to neighbour tunnel systems. The frame has been collected during the ADVANCE Project. A. In red circles appear 2 individuals at dawn; B. In the red circle a single individual and a flat fish transiting just above.

5.5.3 Dominance hierarchy male Nephrops

(Valerio Sbragaglia)

The Norway lobster (*Nephrops norvegicus*) spend most of the day in burrows and forage outside of them according to a diel (i.e. 24-h based) activity rhythm (Bell et al., 2006; Aguzzi and Sardà, 2008). Fighting behavior over burrows have been observed in the wild (Chapman and Rice, 1971) and in the laboratory (Katoh et al., 2008; Aguzzi et al., 2011; Katoh, 2011; Katoh et al., 2013; Sbragaglia et al., 2017). The understanding of how dominance hierarchies influence burrow related behavior of *Nephrops* could be important for estimating *Nephrops* abundances by underwater television surveys, where the presence of intact burrow complexes is used to assess the abundance of *Nephrops* on the basis of the postulated equivalence one burrow/one lobster (reviewed by Sardà and Aguzzi, 2012).

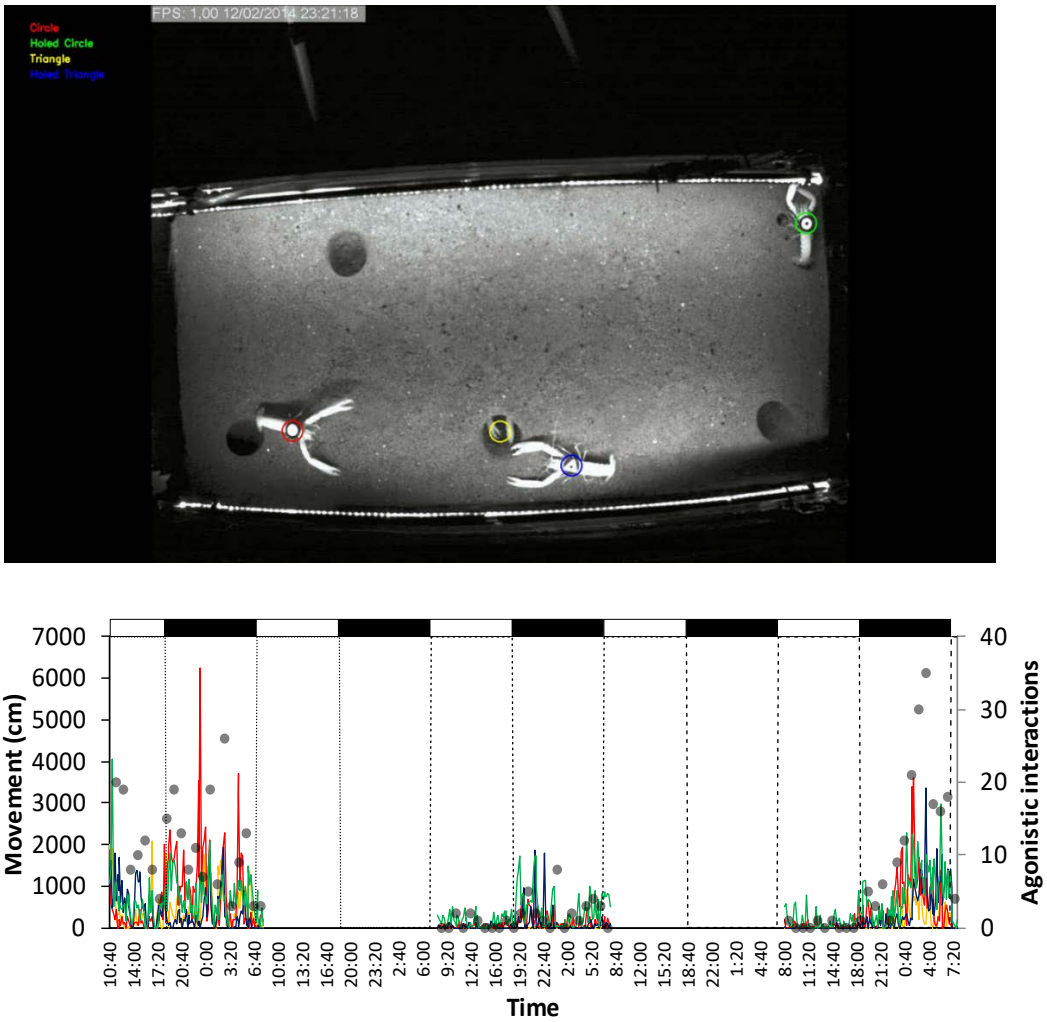

Figure 5.5.3.1. Experimental setup and observations on the dominance hierarchy in a group of male *Nephrops*.

In this context, the present results are of relevance, suggesting that in high-density areas dominant lobsters may evict subordinates and control several burrows at once. Despite the results presented here must be interpreted with caution as the dynamic of burrow occupancy in a closed tank could be different from the situation in the wild, they trigger interesting research questions that could be addressed in the future activity of the WGNEPS.

5.6 ToR h. Developing R scripts for UWTV survey data processing including functions to QC, analyse and visualize data

WGNEPS members will continue to exchange R codes and are encouraged to upload the actual R codes for e.g. quality checks (QC) including Lin's CCC or density and violin plots on the WGNEPS GitHub.

6 Cooperation

- **Cooperation with other WGs**
  WGNEPS provides information for *Nephrops* stock assessments and advice to WGCSE, WGNSSK and WGBIE.

- **Cooperation with Advisory structures**
  There has been or is a good contact to the parental committees SSGIEOM and EOSG. Outside ICES there is a cooperation of the UK labs with JNCC.

- **Cooperation with other IGOs**
  The UK labs provide information through JNCC following an OSPAR request on the occurrence of sea-pens and other ecological information.

7 Summary of Working Group self-evaluation and conclusions

A summary list of the WGNEPS achievements during this cycle is given in section 4 and the full self-evaluation is given in Annex 4. The group recommends continuing a new term in 2019 with slightly revised ToRs.

8 Next meeting

12 – 14 November 2019, Institute of Oceanography and Fisheries (IOF), Split, Croatia.

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NAME	ADDRESS	PHONE/FAX	EMAIL
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*: called in for ToRs a and b, **: joined discussion on ToRs b and f, ***: called in for presentation and discussion on ToR c

Annex 2: Recommendations

RECOMMENDATION	ADRESSED TO
WGNEPS recommends that survey coverage be expanded to other important fisheries that are not currently assessed using fisheries-independent information (e.g. Botney Gut FU5 and Norwegian trench FU32). Additionally, the UWTV survey in FU33, which is currently conducted solely by Denmark, should continue beyond 2019. However, as financial restrictions may limit these activities, advice on the priorisation of surveying these three FUs from ACOM would be highly desireable.	WGNSSK, ACOM
Establish a UWTV meta-database	ICES Data Centre

Annex 3: Adenga

Day 1 Tue 6/11

8:30 Setup of computers, projector and internet connections

9:00 Welcome

Pascal Larnaud (Head of Lorient facilities of IFREMER) and Jean-Philippe Vacherot (local host),

Kai Wieland and Adrian Weetman (co-chairs)

ToR's and adoption of the agenda

9:30 WGNEPS 2018 review of survey activities (ToR a and b)

Nephrops UWTV survey in the Bay of Biscay and implications for advice. Jean-Philippe Vacherot and Spyros Fifas

10:30 - 11:00 Coffee Break

11:00 WGNEPS 2018 review of survey activities (ToR a and b; cont.)

Developments on AFBI trawl and UWTV surveys. Annika Clements **(via Skype)**

Nephrops UWTV and trawl surveys in the Adriatic Sea. Michela Martinelli et al.

UWTV survey *and Nephrops* advice in Icelandic waters. Jónas P. Jónasson

13:00-14:30 Lunch

14:30 Developments on the UWTV survey in the Gulf of Cádiz. Yolanda Vila et al. **(via Skype)**

Developments on the trawl and UWTV survey in Portugal. Cristina Silva **(via Skype)**

Joint Danish/Swedish UWTV survey in the Skagerrak and Kattegat. Kai Wieland and Mats Ulmestrand

15:30 – 16:00 Coffee Break

16:00 Danish UWTV survey Off Horns Rev. Kai Wieland

Update on CEFAS surveys. Robin Masefield

Update on Scottish UWTV surveys. Katie Boyle and Adrian Weetman

Update on Marine Institute Surveys. Jennifer Doyle and Mikel Aristegui

Summing up on survey activities in 2018 and plans for 2019

18:00 Adjourn

Day 2 Wed 7/11

9:00 ***WK Nephrops* outcomes, discussion and conclusions**

Review of SISP UWTV *Nephrops* surveys

10:30-11:00 Coffee Break

11:00 **Review of SISP** UWTV *Nephrops* surveys

13:00-14:30 Lunch

14:30 **Status and plans for ToR c** (To review video enhancement, video mosaicking, automatic burrow detection and other new technological developments)

New monitoring technologies to produce ancillary data on *Nephrops* stock assessment. Jacopo Aguzzi **(via Skype)**

Nephrops norvegicus detection and classification from underwater videos using Deep Neural Network. Atif Naseer **(via Skype)**

15:45 – 16:00 Coffee Break

16:15 FU2021: Review of survey count data (2016-2017). Mikel Aristegui and Jennifer Doyle

Drafting parts for the report

Evaluate template for WG Self-evaluation

18:00 **Adjourn**

Day 3 Thu 8/11

9:00 **Status and plans for ToR f** (Develop an international database which will hold burrow counts, ground shape files and other data associated with UWTV surveys, Develop an international database on trawl surveys)

Status and plans for ToR h (Developing R scripts for UWTV survey data processing including functions to QC, analyse and visualize data, and interface the tools with the database (ToR f))

Adoption of final version of SISP

10:30-10:45 Coffee Break

10:45 **Adoption of final version of SISP (cont.)**

Meeting in 2018 (venue and dates)

Status and for plans for ToR e (Discuss the utility of UWTV and trawl *Nephrops* surveys as platforms for the collection of data for OSPAR and MFSD indicators)

Review of existing datasets to evaluate possible factors affect burrow emergence (ToR g)

Status and plans for the review paper

Adoption of WG self-evaluation

Other scientific contributions

Recommendations from other expert groups to WGNEPS (if there are any)

Update of Action list

Plenary on draft of recommendations and draft report

Update of WG member list

13:00-14:30 Lunch

Report writing

15:45 – 16:15 Coffee Break

Report writing (cont.)

Official closure

17:30 Adjourn

Annex 4: Working group self-evaluation

Working Group name: Working Group on Nephrops Surveys (WGNEPS)

Year of appointment: 2016

Current Chairs: Adrian Weetman (UK Scotland) and Kai Wieland (Denmark).

Venues, dates and number of participants per meeting:

7–8 November 2016, Reykjavik, Iceland (19 participants)
28 November – 1 December 2017, Heraklion, Greece (19 participants)
6 – 8 November 2018, Lorient, France (18 participants)

WG Evaluation

If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

WGNEPS is committed with Science Plan's topics 25, 27, 28, 30 and 31. The group has made significant contributions to the specified topics namely in the identification of monitoring requirements and quality of data estimates (SP 25); on the development of strategies to fill gaps in knowledge and methodological monitoring (SP 27); on the promotion of new technologies for observation and monitoring (SP 28); to comply with requests from other WG's and Experts Groups on the quality of its data products (SP30) and to ensure the best practices and the establishment of guidelines and quality standards for survey sampling programmes (SP 31)

In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

- Review of changes to design, coverage and equipment for the various Nephrops UWTV and trawl surveys.
- Review of outcomes from benchmarks for Nephrops stocks in respect to the quality of the Nephrops survey data used in advice.
- Applying recent technology developments such as HD cameras and fibre optic cables in Nephrops UWTV surveys.
- Update of work to create video mosaics from UWTV survey footages.
- Completion of Cooperative Research Report "Using underwater surveys to assess and advise on Nephrops stocks (CRR #340)
- Defining data structure and requirements for the UWTV database for Nephrops.
- Development of R-scripts for data processing and quality control of Nephrops survey data.
- Consideration the results of experimental and fieldwork on Nephrops burroew emergence to improve the interpretation of the survey results
- Review the outcomes of Nephrops burrow counting workshops in 2016 and 2018 to improve the guidelines for the survey data analysis.
- Completion of final draft of the manual for Nephrops Underwater TV Surveys for the Series of ICES Survey Protocols (SISP).

Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

The surveys coordinated by WGNEPS provide fishery-independent survey estimates of abundance to assessment working groups annually, such as: WGNSSK, WGCSE and WGBIE.

Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

UWTV surveys are used in the UK for providing information on the occurrence of sea pens and other ecological information to JNCC following an OSPAR request. UK information on marine litter is provided to OSPAR.

Please indicate what difficulties, if any, have been encountered in achieving the work plan.

The publication of the CRR was delayed and a review paper on possible factors affecting burrow emergence could not be completed due to other commitments of WG members, missing funding and the change of the chair in past 3 year period.

Future plans

Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

Yes as the core actions of this group includes:

- Planning and coordination of *Nephrops* Surveys;
- Delivery of annual data products from *Nephrops* surveys particular in the Irish Sea, North Sea, Celtic Sea, North Atlantic (West off Ireland, South off Iceland, Bay of Biscay, Gulf of Cadiz, West off Portugal) and the Adriatic Sea;
- Provide quality assured fishery-independent abundance estimates with the lowest possible level of uncertainty.

A corresponding category 2 draft resolution with a proposed revision of the current ToRs will be submitted together with the final draft report to the secretariat.

If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

(*If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat*.)

What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific).

Annex 5: List of presentations

(in order of appearance)

Spyros Fifas, Jean-Philippe Vacherot, Michèle Salaun, Jean-Jacques Rivoalen: FU23-24 Nephrops - Preliminary analysis of uwtv survey 2018 results. 22 pp.

Annika Clements: FU15 Western Irish Sea Nephrops surveys. 15 pp.

Michela Martinelli, Medvešek D., Belardinelli A., Isajlović I., Angelini S., Domenichetti F., Morello E.B., Penna P., Croci C., Micucci D., Scarpini P., Guicciardi S., Santojanni A., Vrgoč N., Arneri E. et al.: ADRIATIC UWTV SURVEYS and Pomo monitoring activity. 33 pp.

Yolanda Vila, C. Burgos and M. Soriano: Developments on the UWTV survey in the Gulf of Cadiz (FU 30). 12 pp.

Christina Silva: FU 28 – 29 (SW & S Portugal). 10 pp.

Jónas Páll Jónasson, Julian Burgos, Haraldur Einarsson, Arnþór, Kristjánsson, Anna Ragnheiður Grétarsdóttir, Hlynur

Þorleifsson, Auður Bjarnadóttir & Hjalti Karlsson: Development of UWTV survey in Icelandic waters. 24 pp.

Kai Wieland, Mats Ulmestrand, Jordan Feekings, Sven Koppetsch, Annegrete Dreyer-Hansen, Maria Jarnum, Gert Holst, Ronny Sørensen: *Nephrops* UWTV survey in the Skagerrak and Kattegat (FU 3&4) in 2017 and 2018. 8 pp.

Kai Wieland, Jordan Feekings, Annegrete Dreyer-Hansen, Maria Jarnum, Gert Holst, Ronny Sørensen: *Nephrops* UWTV survey Off Horns Rev (FU 33) in 2017 and 2018. 7 pp.

Robin Masefield: Survey results & Assessment summary FU 6 and FU 14.10 pp.

Katie Boyle: MSS 2018 UWTV surveys. 14 pp.

Jennifer Doyle & Mikel Aristegui et al.: 2018 Update on Marine Institute Ireland *NEPHROPS* UWTV SURVEYS. 21 pp.

Jacopo Aguzzi: New monitoring technologies to produce ancillary data on Nephrops stock assessment. 11 pp.

Atif Naseer: Nephrops norvegicus detection and classification from underwater videos using Deep Neural Network. 20 pp.

Mikel Aristegui and Jennifer Doyle: FU2021: Review of survey count data 2016 &-2017. 12 pp.

Annex 6: Action list

	Action	Addressed to	Action latest before
1	Provide outstanding parts of the WG report	All WG members	At latest 1/12-2018
	Review and comment on completed draft report	All WG member	At latest 8/12-2018
2	Inform ICES on status, plans and progress on UWTV meta-database, and shapefiles for FUs- and survey domain polygons	Adrian contact ICES Data Centre (Neil Holdsworth, Carlo Pinto)	asap
3	Update draft specifications for the UWTV meta-database for report	Adrian	8/12-2018
4	Arrange meeting with ICES Data Centre on UWTV meta-database updated specifications	Adrian	Before next meeting
5	Finalize SISP	Jonas, Jennifer	1/12-2018
6	Submit SISP to ICES	Kai	At latest 8/12-2018
7	Update/Upload R scripts for UWTV survey data analysis and quality control on GitHub	Robin and other WG members	Ongoing
8	Contact and invite users of UWTV survey data for ecosystem studies to provide feedback	Annika	Before next meeting
9	Plan Danish/Swedish burrow counting workshop, circulate information to WG members and invite external expert	Kai	As soon as venue and dates are identified

Annex 7: Analyses of the review of survey count data FU 20-21 for 2016-2017

(Mikel Aristegui, Jennifer Doyle)

R version 3.5.1 (2018-07-02) and several R libraries were used to generate this document (Table 1).

Table 1. R libraries and versions used in this R-markdown document

Package	Version
captioner	2.2.3
data.table	1.11.4
epiR	0.9-96
fields	9.6
grid	3.5.1
gridExtra	2.3
knitr	1.20
lme4	1.1-17
mapplots	1.5.1
mapproj	1.2.6
maps	3.3.0
maptools	0.9-2
reshape2	1.4.3
rgdal	1.3-3
RGeostats	11.2.3
RODBC	1.3-15
shapefiles	0.7
sqldf	0.4-11
tidyverse	1.2.1
vioplot	0.2

1 Introduction

This document details the review undertaken as a result of plenary discussions at WGCSE 2018 in May, where it was recommended by the WG to review 20% of stations in both years 2016 and 2017 given the substantial increase in 2017 abundance for FU20-21.

The same process was carried out for both 2016 and 2017 reviews and they are fully detailed in this document, first for 2016 and second for 2017. Both years follow the same structure:

- First we compare the original sea count data and the historical review stations counted onboard during the 2018 UWTV FU20-21 survey (16 randomly selected stations for each of the two years):
  - The review stations were interspersed with the current 2018 stations and distributed equally among the 6 person counting team
  - All counts at sea were undertaken once the reference footage was passed
  - All survey counts (including the historical review) were quality controlled using Lin's CCC statistical method with a threshold of 0.5
- Secondly we report the full kriging procedure for each survey, but replacing the counts for the 16 randomly selected stations, which were recounted onboard in 2018. The same basic steps were carried out as in the original years:
  - Construction of experimental variogram, a model variogram, was produced with a spherical model
  - A krigged grid file was created using all data points as neighbours
  - The same boundary was used to estimate the domain area, the mean density, total burrow abundance and survey precision calculated.

2 2016: COUNTS COMPARISON

2.1 Sample random stations

We are going to select the stations that we will review from 2016 FU20-21 footage.

- We will take only stations with more than 15 burrows for the entire TV station.
- From these stations greater than 15, we will take the stations with highest counts (two station outliers).
- From the rest of the stations > 15 burrows, we will take a random sample of 20% stations (14 stations).

In total, we will review 16 stations from 2016 FU20-21 footage.

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/2018 Labadie/Histori
cal_Review")

## Read the data and subset the year of interest
dat <- fread("fu2021_tv_final_2017.csv", select = c("FU", "Survey", "
Year",
    "Station", "Count", "MidDeglong", "MidDegLat", "Ground"))
d <- subset(dat, Year == 2016)
```

```
## Identify the outliers in each of the Years
d2016 <- subset(dat, Year == 2016)
out2016 <- boxplot(d2016$Count ~ d2016$Year, plot = F)$out
d2016[d2016$Count %in% out2016]

##      FU  Survey Year Station Count MidDeglong MidDegLat  Ground
## 1: 2021 CV16024 2016     232 119.5 -8.3656226 49.965505 Labadie
## 2: 2021 CV16028 2016     171 122.0 -7.4568126 50.742093 Labadie

### Steps: Remove Stations with Count < 15; Remove Outliers Stations;
### Sample a % from the rest of the Stations; Add the Outlier Station
s

### Remove Stations with Count < 15
more15 <- subset(d, Count >= 15)

### Calculate Stations in each Year with Count >= 15
more15.year <- group_by(more15, Year)
TotStat2016 <- sum(more15.year$Year == 2016)
TotStat2016

## [1] 71

### Remove Outliers Stations
more15out <- more15[more15$Year == 2016 & !more15$Count %in% out2016,
]

### SAMPLE p percentages ----
p <- seq(0.1, 0.3, by = 0.05)  # set the % you want to check

samp <- list()  # setting container for the loop
review <- list()  # setting container for the loop
SamStat2016 <- list()  # setting container for the loop

for (i in 1:length(p)) {
    ### sample p% from each Year and storage in samp
    samp[[i]] <- as.data.frame(more15out %>% group_by(Year) %>% sampl
e_frac(p[i]))

    ### add the Ourlier Stations
    review[[i]] <- rbind(samp[[i]], more15[more15$Year == 2016 & more
15$Count %in%
        out2016, ])
    ### ordering the data.frames by Year and Station numbers
    review[[i]] <- review[[i]][order(review[[i]]$Year, review[[i]]$St
ation)]

    #### How many Stations we would review with this method for each
p%?
    SamStat2016[[i]] <- sum(review[[i]]$Year == 2016)

    ### Rename the dataframes inside the containers with the their p%
values
    names(samp)[i] <- paste0("sample ", p[i] * 100, "% + outliers")
    names(review)[i] <- paste0("sample ", p[i] * 100, "% + outliers")
    names(SamStat2016)[i] <- paste0("sample ", p[i] * 100, "% + outli
ers")
}
```

```
### How many Stations to review with this method, under each p% value
?
knitr::kable(data.frame(n_2016 = unlist(SamStat2016)), caption = past
e0("Number of",
    " stations needed to be reviewed under each of the percentage opt
ions"))
```

Table 2. Number of stations needed to be reviewed under each of the percentage options

	n_2016
sample 10% + outliers	9
sample 15% + outliers	12
sample 20% + outliers	16
sample 25% + outliers	19
sample 30% + outliers	23

2.1.1 We chose to sample 20% + outliers

```
### Which Stations do we have to review with this method?
Station.rev <- lapply(review, select, c(Year,Station))
knitr::kable(Station.rev$"sample 20% + outliers", # insert the de-
sired p%
             caption = '2016 FU20-21 UWTV Review stations ID')
```

Table 3. 2016 FU20-21 UWTV Review stations ID

Year	Station
2016	171
2016	173
2016	175
2016	178
2016	186
2016	189
2016	196
2016	201
2016	202
2016	209
2016	222
2016	223
2016	224
2016	231
2016	232
2016	244

‘

2.2 Map showing the 2016 stations and the 20% historical review stations

```
# read shapefile as a SpatialPolygonsDataframe
FG <- readShapePoly("//Galwayfs03/Nephrops/Surveys/ArcGis/ShapefilesR
/NephropsGrounds_All",
    proj4string = CRS("+proj=longlat +datum=WGS84"))
EU <- readShapePoly("//Galwayfs03/Nephrops/Surveys/ArcGis/ShapefilesR
/Europe",
    proj4string = CRS("+proj=longlat +datum=WGS84"))

m <- ggplot() + geom_polygon(data = EU, aes(x = long, y = lat, group
= group),
    fill = "#006837") + geom_polygon(data = FG, aes(x = long, y = lat
,
    group = group), fill = "Light Grey")

latlimits <- c(49.6, 51.2)
longlimits <- c(-7, -9.2)

dat2 <- d %>% rename(lon = MidDeglong) %>% rename(lat = MidDegLat)
dat2 <- data.frame(dat2)
dat3 <- subset(dat2, Station %in% real.stn)

m + geom_point(data = dat3, aes(x = lon, y = lat), shape = 1, size =
8,
    colour = "red") + geom_text(data = dat2, aes(x = lon, y = lat, la
bel = (Station)),
    size = 4) + theme_bw() + coord_cartesian(xlim = longlimits, ylim
= latlimits) +
    labs(y = "Latitude", x = "Longitude")
```

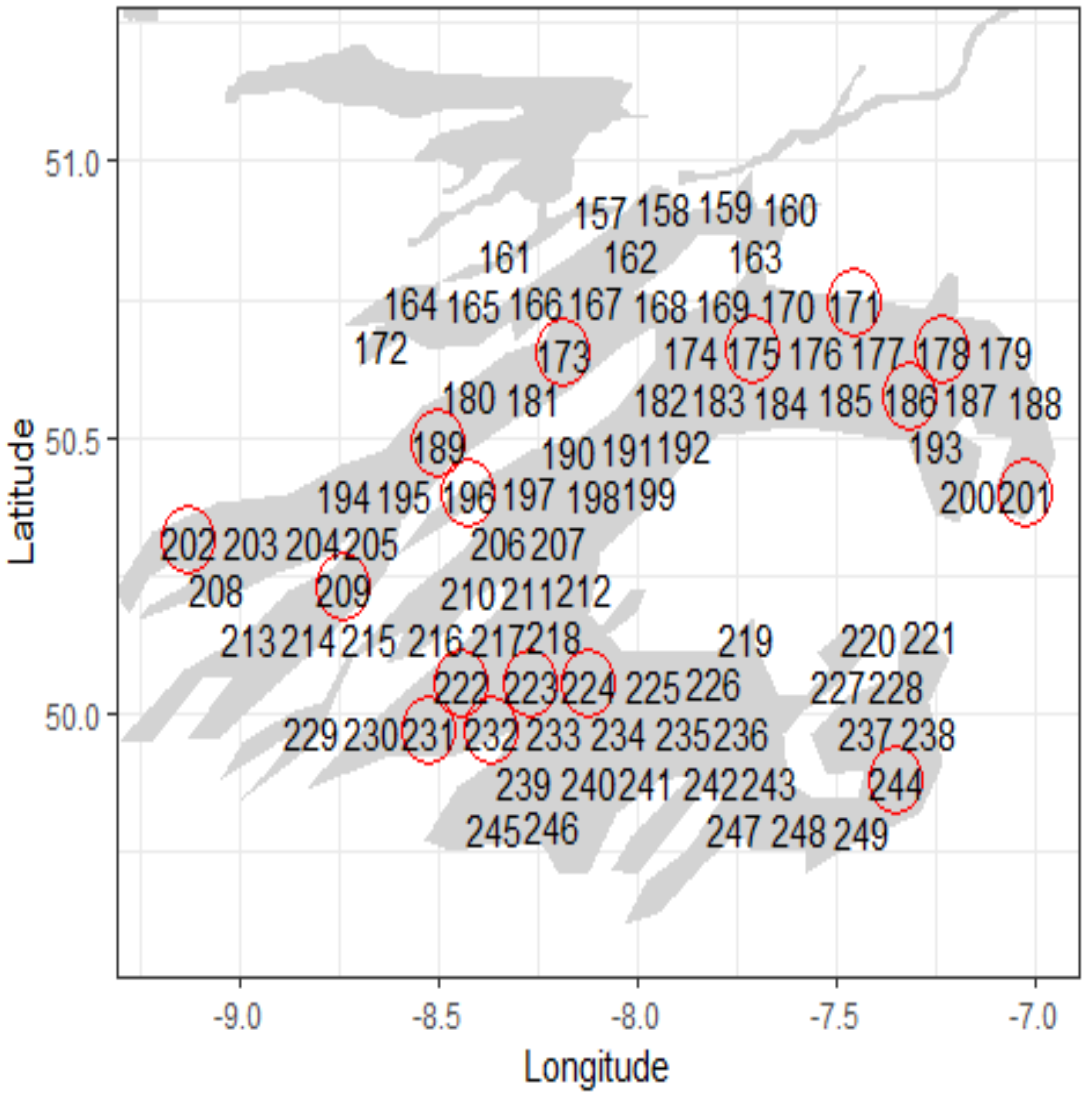


Figure 1: Map showing 2016 stations and historical review stations denoted by red circle.

2.3 Read in the validation data

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2016/Final Data/")
# ensure delete additional minutes in local survey database run queri
es
# 1-5 to generate Recounts-Clean or pop them in here to code

channel <- odbcConnectAccess(paste0("N:/Surveys/UWTV SURVEYS FU2022 C
ELTIC SEA/",
    "Historical review Labadie 2016/Final Data/NEPHROPS_MULTILOG_CV16
024_Labadie"))

dataframe <- sqlFetch(channel, "Recounts")

recounts.clean <- dataframe[-which(dataframe$StartTime - dataframe$St
opTime >
    30), ]

stns <- read.csv("id_of_stations_to_review_dvd.csv")
```

```
stns <- stns[1:32, c("Year", "Station", "Count", "Count2")]
stns16 <- subset(stns, Year == 2016)

# we select the validation reviewers
rec <- recounts.clean[which(recounts.clean$Video_Line_Name %in% uniqu
e(stns16$Station)),
    ]
Recounts <- subset(rec, VideoOperatorID %in% c(12, 15, 34, 35, 36, 37
))

Ops <- sqlFetch(channel, "Video_Operator")
close(channel)
```

2.4 Check number of recount stations

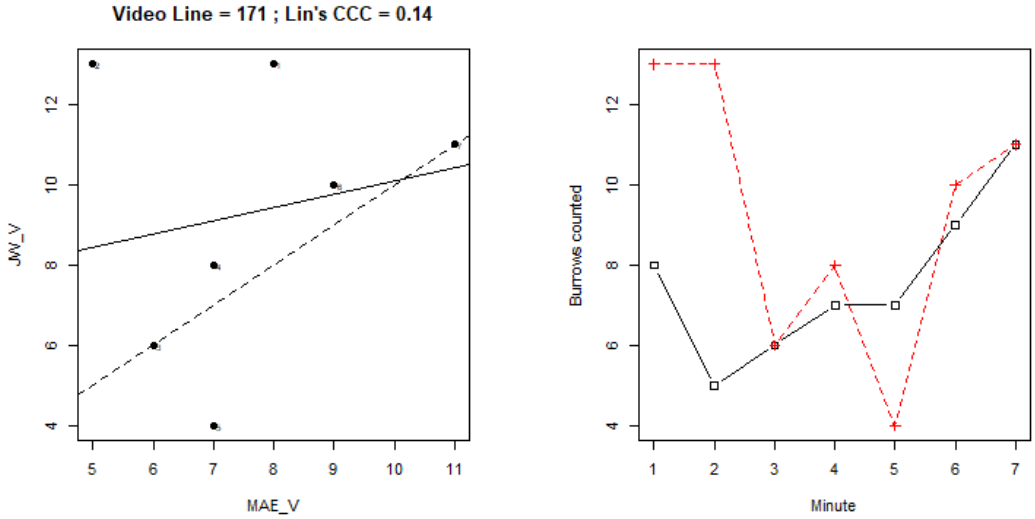
```
length(unique(Recounts$Video_Line_Name))

## [1] 16

Recounts <- Recounts[order(Recounts$Video_Line_Name, Recounts$SurveyI
D,
                           Recounts$VideoOperatorID, Recounts$Minute)
, ]

selst <- Recounts %>% group_by(Video_Line_Name) %>%
  summarise(hatn = sum(BurrowCount)/length(BurrowCount)) %>% filter(h
atn > 1.5)

selst <- as.list(selst[1])

SummedBurrow<-aggregate(BurrowCount~Video_Line_Name, sum, data = Reco
unts)
ZeroBurrow<-subset(SummedBurrow, BurrowCount > 0)
RecountsP<-subset(Recounts, Video_Line_Name %in% selst$Video_Line_Nam
e)
length(unique(Recounts$Video_Line_Name))

## [1] 16
```

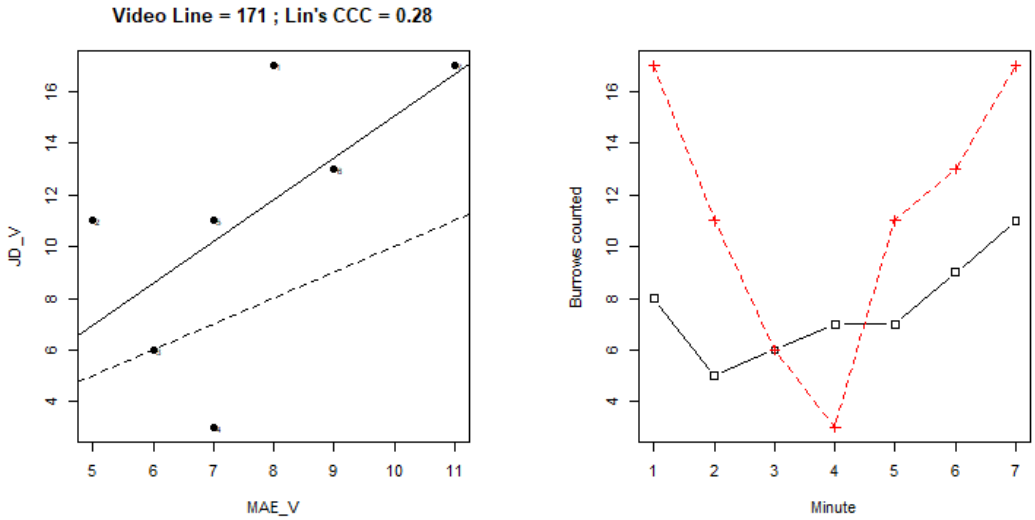
2.5 Quality control using Lin's CCC test

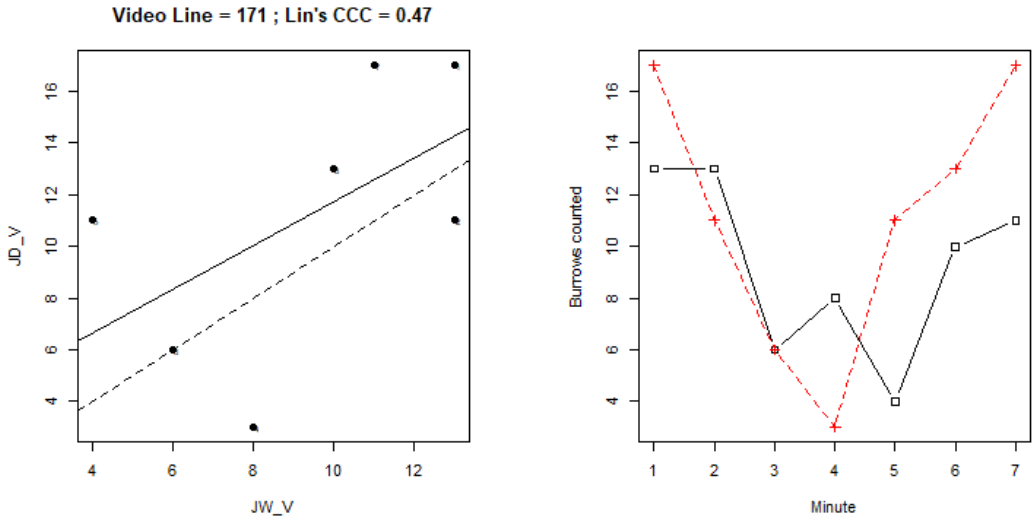
As standard on UWTV surveys run the counts to check counter performance using a threshold of 0.5 for FU20-21.

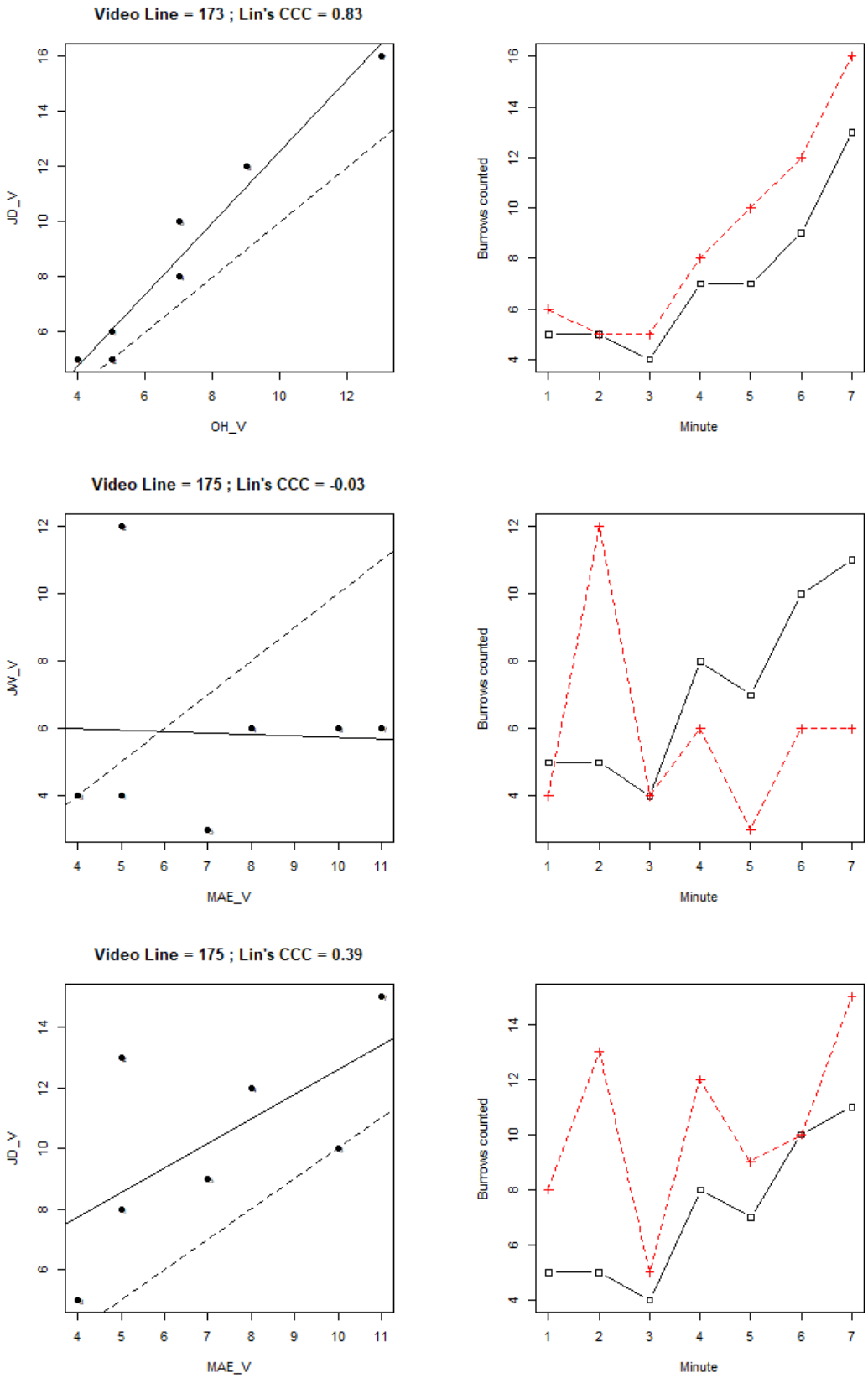
```
Lins <- 0.5
Oid <- sort(unique(RecountsP$Video_Line_Name))
par(mfrow = c(3, 2))
for (o in c(1:length(Oid))) {
    temp <- RecountsP[RecountsP$Video_Line_Name == Oid[o], ]
    temp <- temp[order(temp$Minute), ]

    Rs <- unique(temp$VideoOperatorID)
    l <- length(Rs)
    if (l > 1) {
```

```
        for (i in c(1:(l - 1))) {
            for (j in c((i + 1):l)) {
                temp2 <- temp[temp$VideoOperatorID %in% c(Rs[i], Rs[j
]),
                  ]
                temp2 <- dcast(temp2, Minute ~ VideoOperatorID, value
.var = "BurrowCount",
                  sum)
                c1 <- as.numeric(names(temp2[2]))
                c2 <- as.numeric(names(temp2[3]))
                c1 <- Ops$Initials[match(c1, Ops$VideoOperatorID)]
                c2 <- Ops$Initials[match(c2, Ops$VideoOperatorID)]

                tmp.ccc <- epi.ccc(temp2[, 2], temp2[, 3], ci = "z-tr
ansform",
                  conf.level = 0.95)
                z <- lm(temp2[, 3] ~ temp2[, 2])
                par(pty = "s")
                plot(temp2[, 2], temp2[, 3], xlab = c1, ylab = c2, pc
h = 16,
                  main = paste("Video Line =", unique(temp$Video_Line
_Name),
                    "; Lin's CCC =", round(tmp.ccc$rho.c[1], 2), sep
= " "))
                abline(a = 0, b = 1, lty = 2)
                abline(z, lty = 1)
                text(temp2[, 2] + 0.1, (temp2[, 3]), temp2[, 1], cex
= 0.6)

                plot(temp2$Minute, temp2[, 2], type = "b", col = 1, p
ch = 0,
                  lty = 1, xlab = "Minute", ylab = "Burrows counted",
xlim = range(temp2$Minute),
                  ylim = range(temp2[, 2:3]))
                points(temp2$Minute, temp2[, 3], col = 2, pch = 3)
                lines(temp2$Minute, temp2[, 3], col = 2, lty = 2)

                LinsVL <- as.data.frame(c(unique(temp$Video_Line_Name
),
                  Rs[i], Rs[j], round(tmp.ccc$rho.c[1], 2)))
                names(LinsVL) <- c("VideoLine", "Counter1", "Counter2
",
                  "LinsCCC")
                Lins <- as.data.frame(rbind(LinsVL, Lins))
            }
        }
    }
}
```

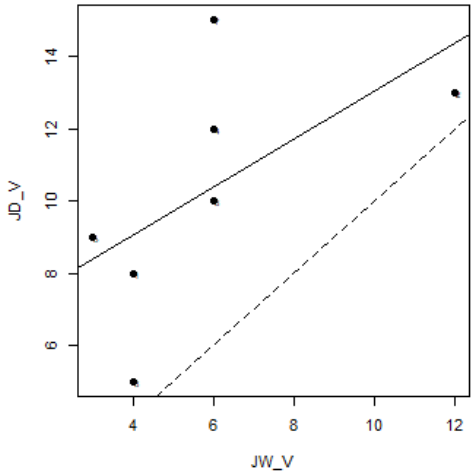

Video Line = 171 ; Lin's CCC = 0.14
JW_V
MAE_V
Burrows counted
Minute

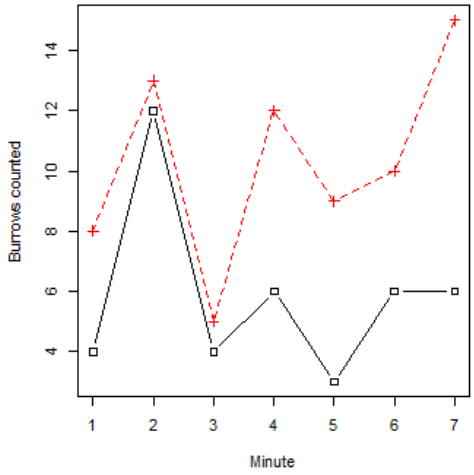

Video Line = 171 ; Lin's CCC = 0.28
JD_V
MAE_V
Burrows counted
Minute


Video Line = 171 ; Lin's CCC = 0.47
JD_V
JW_V
Burrows counted
Minute

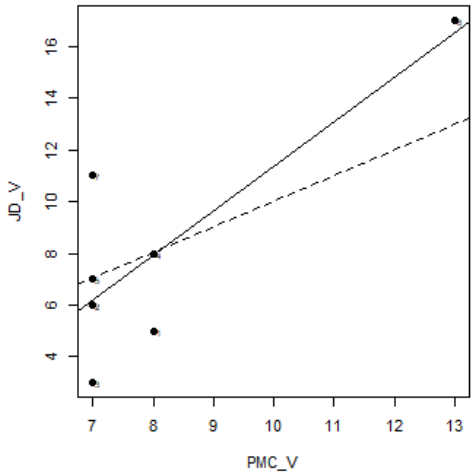

Video Line = 173 ; Lin's CCC = 0.83
JD_V
OH_V
Burrows counted
Minute
Video Line = 175 ; Lin's CCC = -0.03
JW_V
MAE_V
Burrows counted
Minute
Video Line = 175 ; Lin's CCC = 0.39
JD_V
MAE_V
Burrows counted
Minute

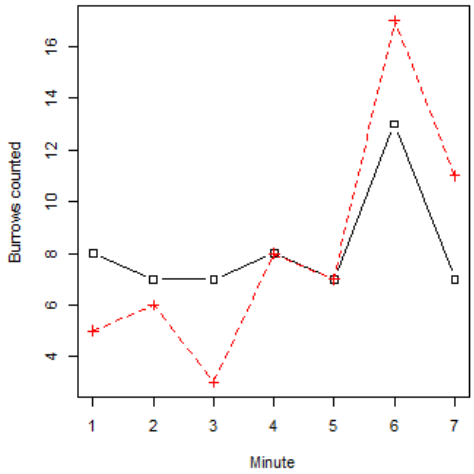
Video Line = 175 ; Lin's CCC = 0.27



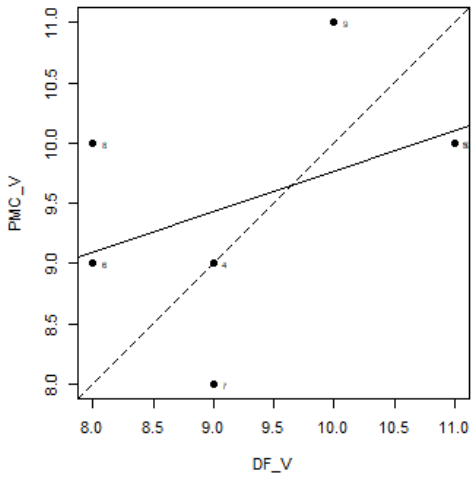


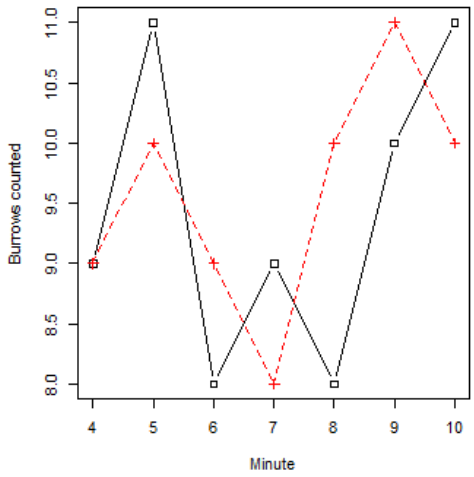
Video Line = 178 ; Lin's CCC = 0.63

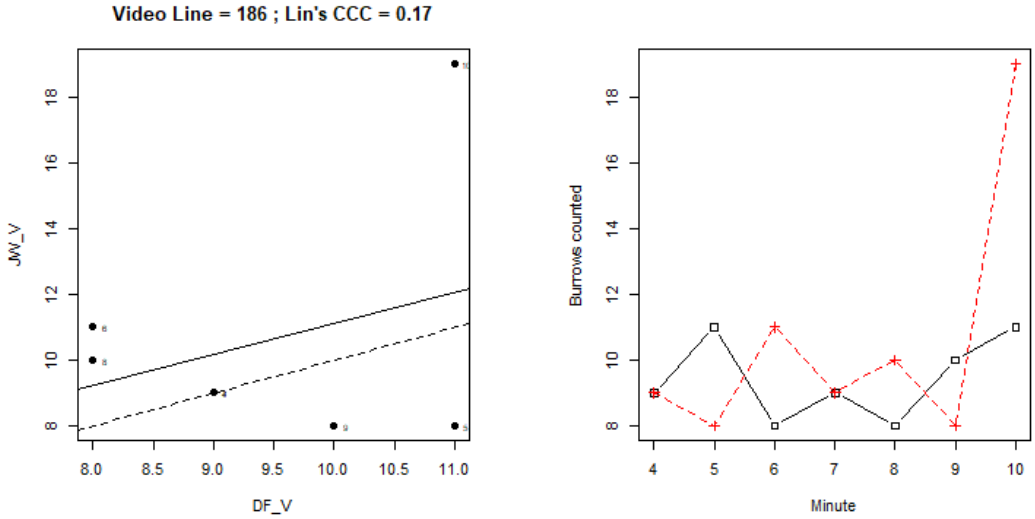


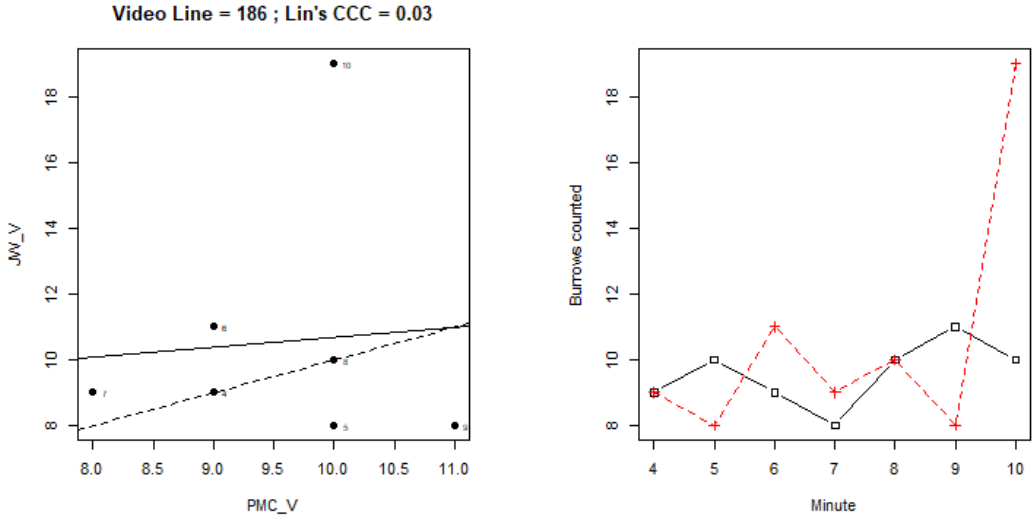


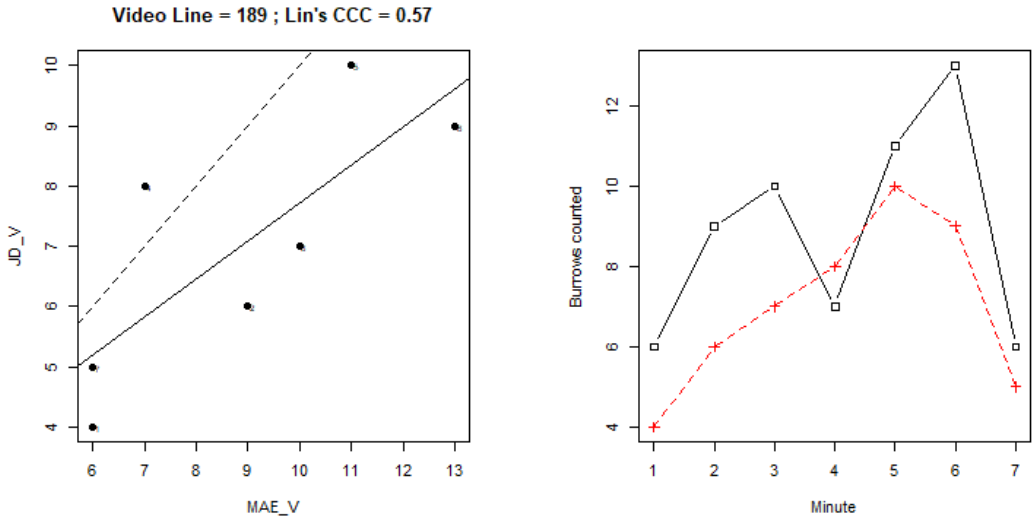
Video Line = 186 ; Lin's CCC = 0.42

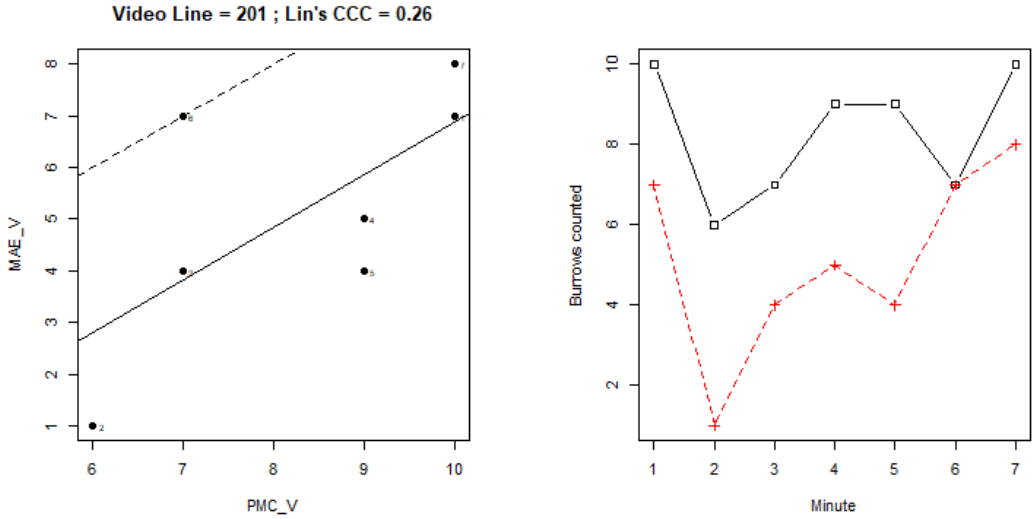


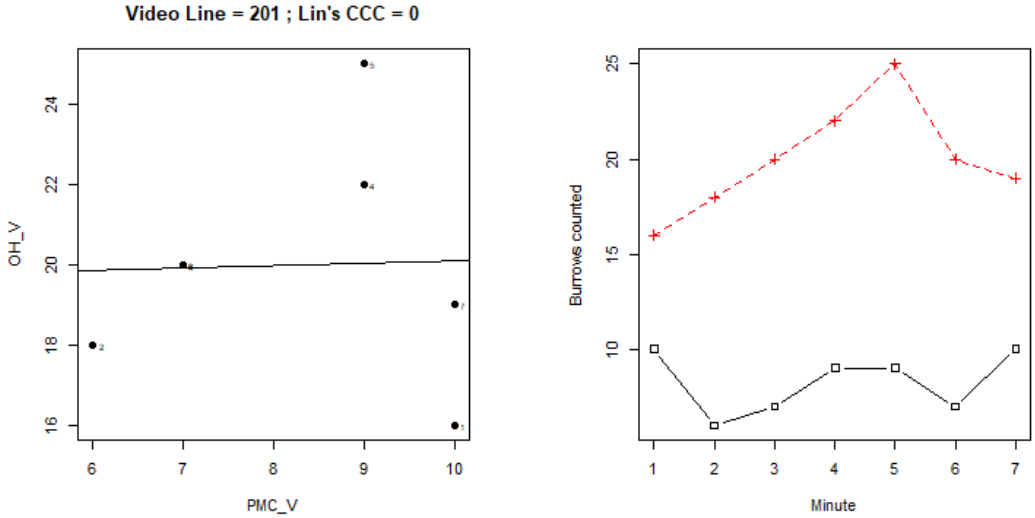


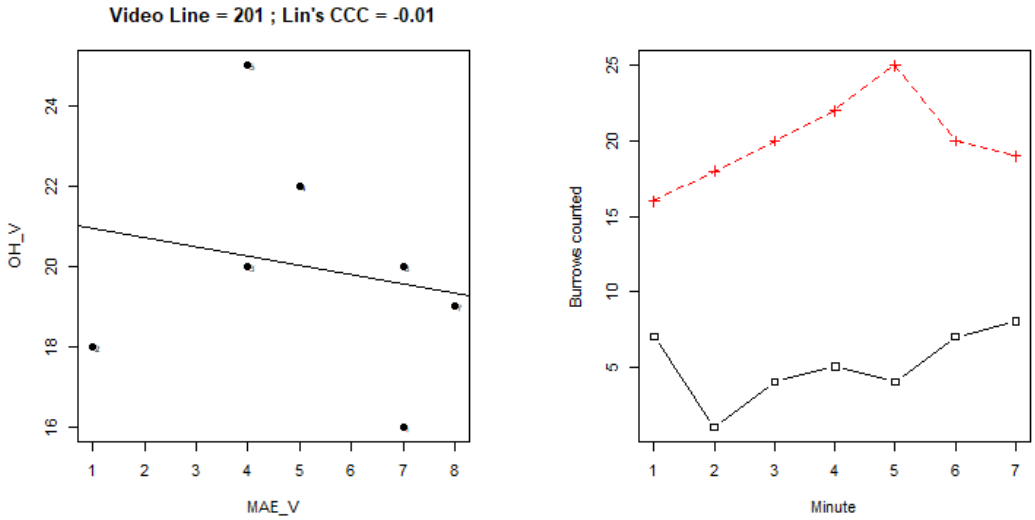

Video Line = 186 ; Lin's CCC = 0.17
JW_V
DF_V
Burrows counted
Minute

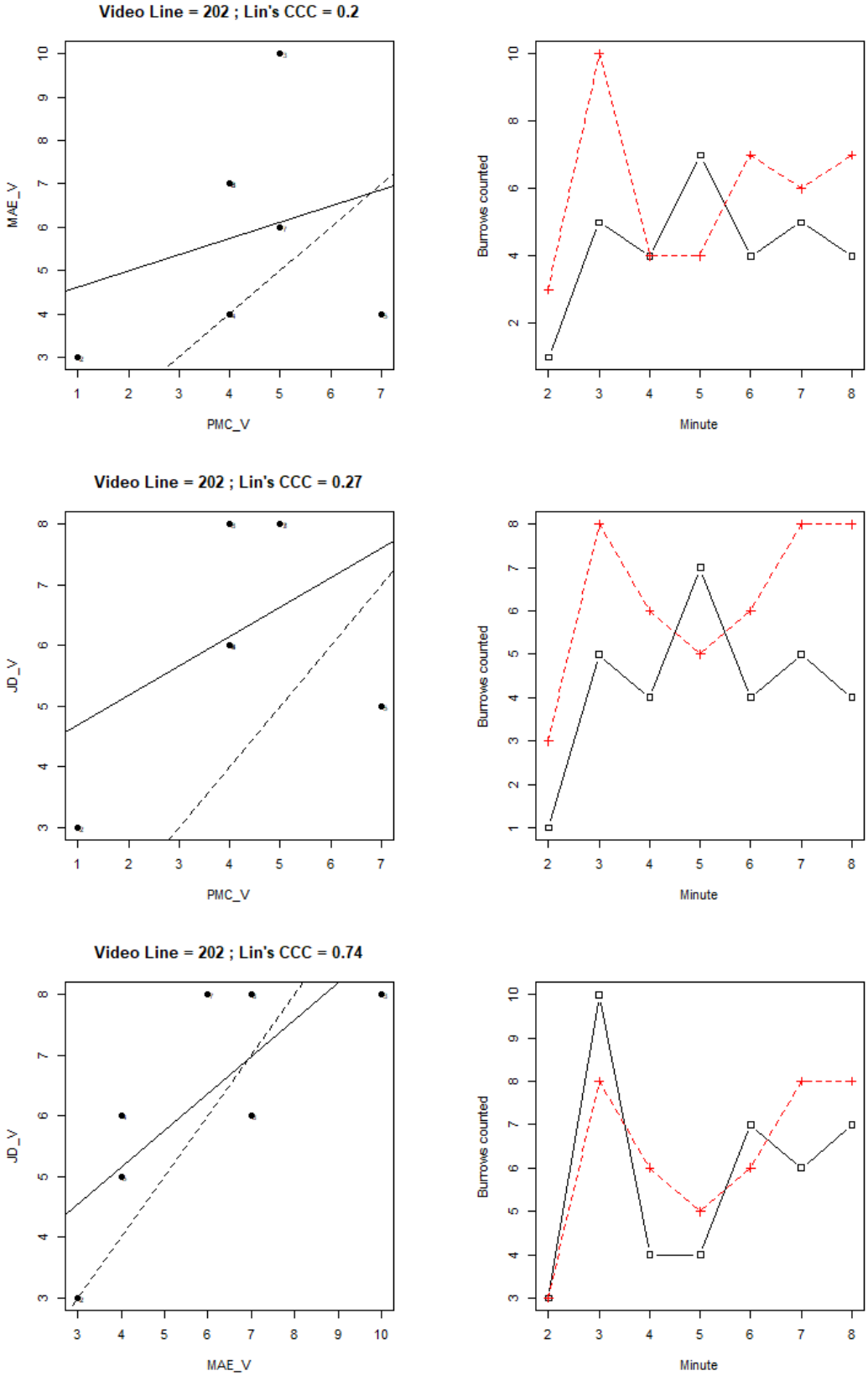

Video Line = 186 ; Lin's CCC = 0.03
JW_V
PMC_V
Burrows counted
Minute

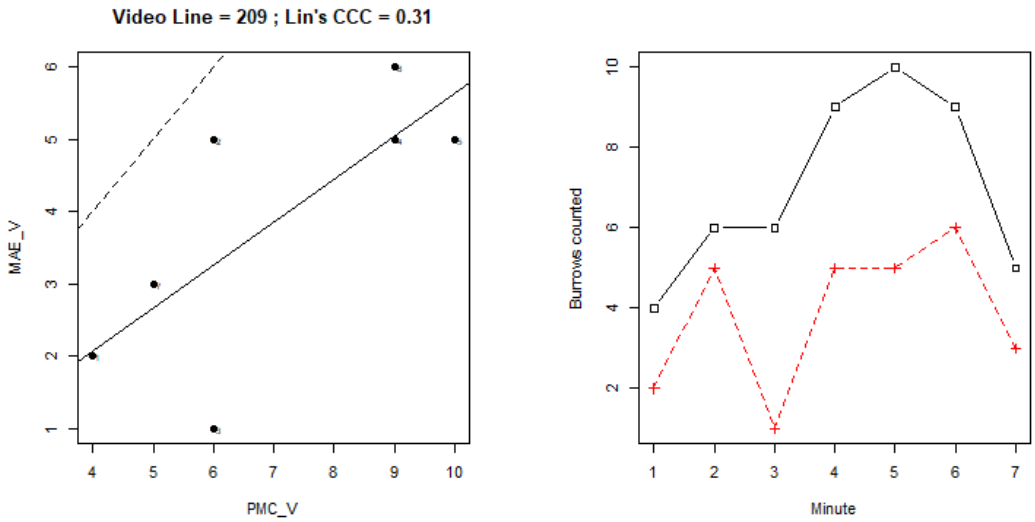

Video Line = 189 ; Lin's CCC = 0.57
JD_V
MAE_V
Burrows counted
Minute

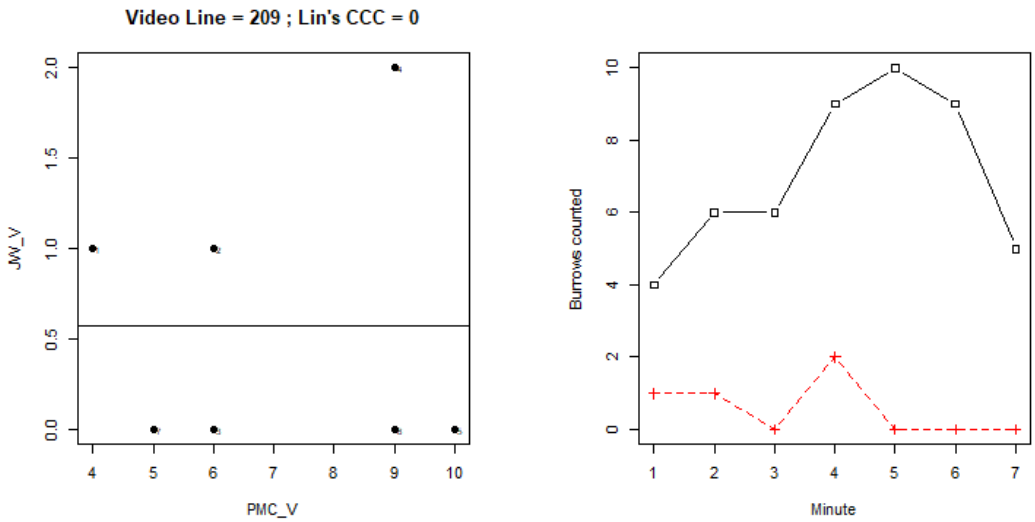

Video Line = 201 ; Lin's CCC = 0.26
MAE_V
PMC_V
Burrows counted
Minute

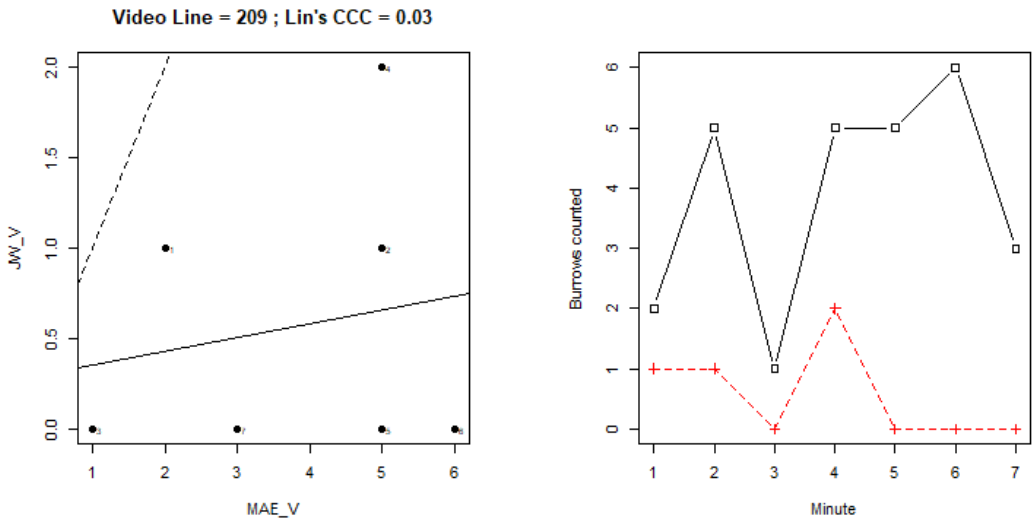

Video Line = 201 ; Lin's CCC = 0
OH_V
PMC_V
Burrows counted
Minute

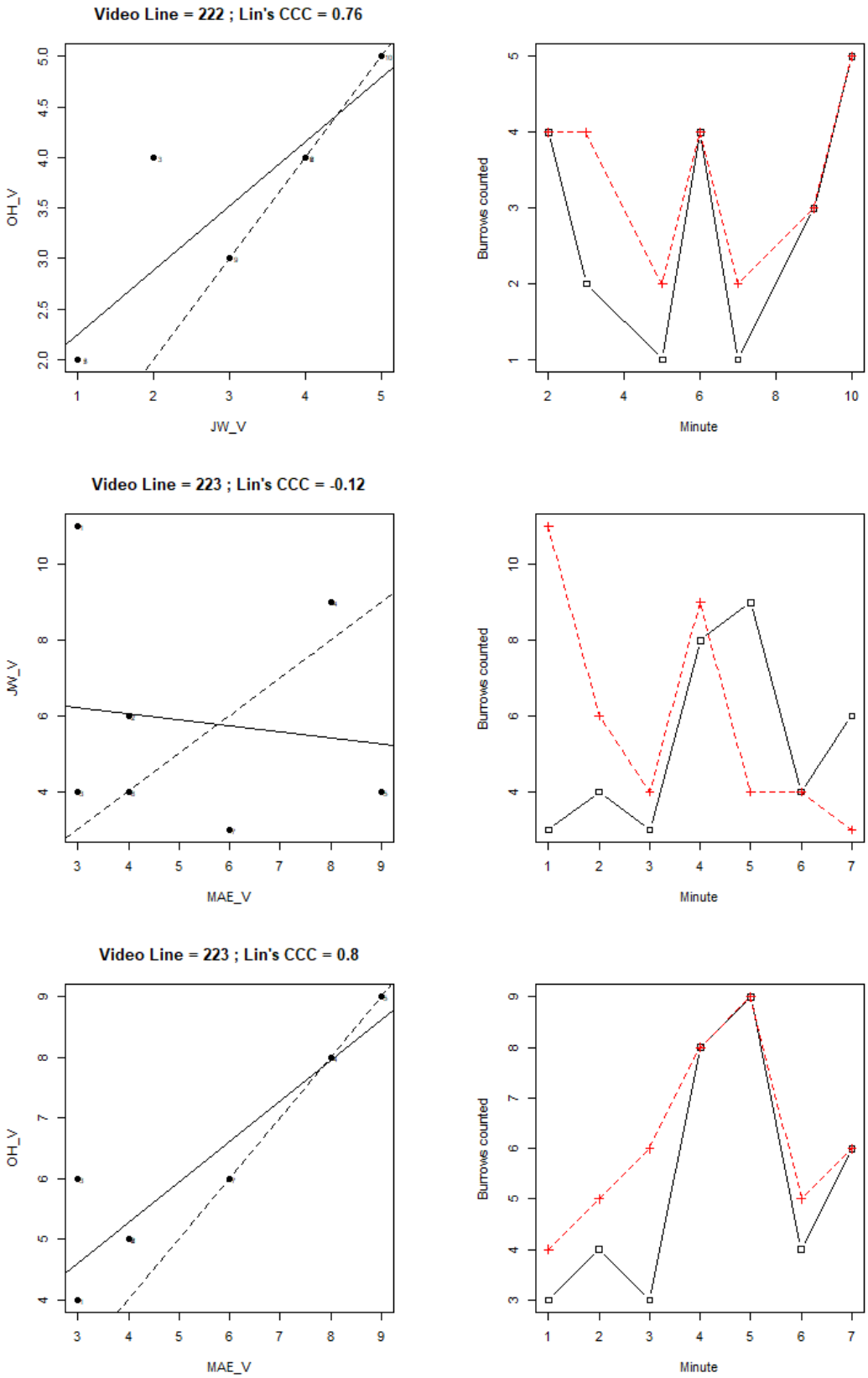

Video Line = 201 ; Lin's CCC = -0.01
OH_V
MAE_V
Burrows counted
Minute


Video Line = 202 ; Lin's CCC = 0.2
MAE_V
PMC_V
Burrows counted
Minute
Video Line = 202 ; Lin's CCC = 0.27
JD_V
PMC_V
Burrows counted
Minute
Video Line = 202 ; Lin's CCC = 0.74
JD_V
MAE_V
Burrows counted
Minute

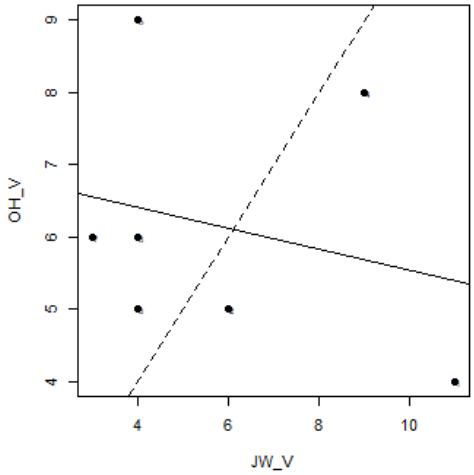

Video Line = 209 ; Lin's CCC = 0.31
MAE_V
PMC_V
Burrows counted
Minute

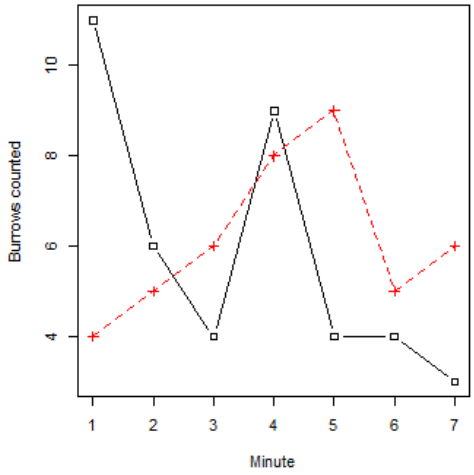

Video Line = 209 ; Lin's CCC = 0
JW_V
PMC_V
Burrows counted
Minute


Video Line = 209 ; Lin's CCC = 0.03
JW_V
MAE_V
Burrows counted
Minute

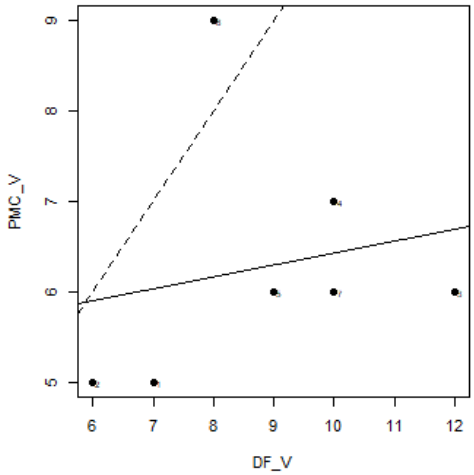

Video Line = 222 ; Lin's CCC = 0.76
OH_V
JW_V
Burrows counted
Minute
Video Line = 223 ; Lin's CCC = -0.12
JW_V
MAE_V
Burrows counted
Minute
Video Line = 223 ; Lin's CCC = 0.8
OH_V
MAE_V
Burrows counted
Minute

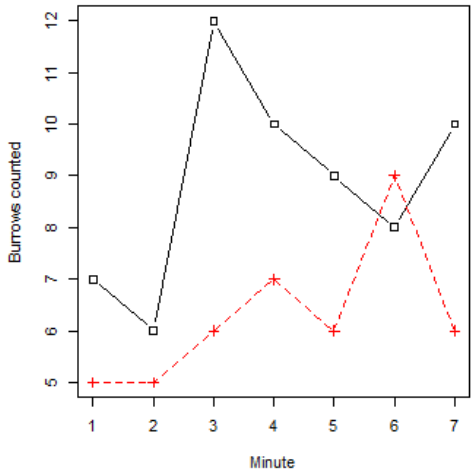
Video Line = 223 ; Lin's CCC = -0.21



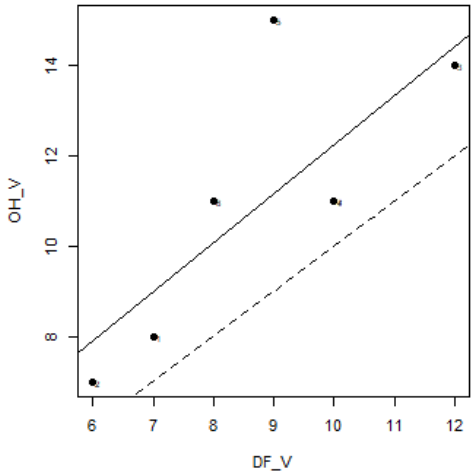


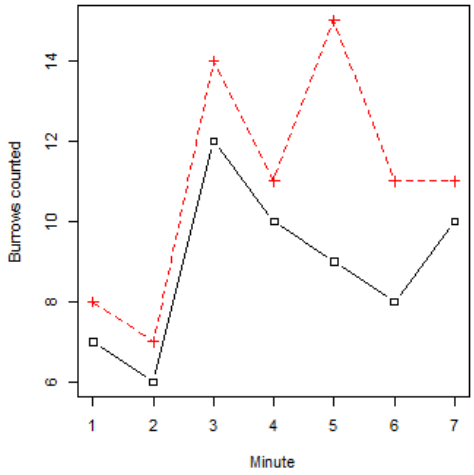
Video Line = 224 ; Lin's CCC = 0.08

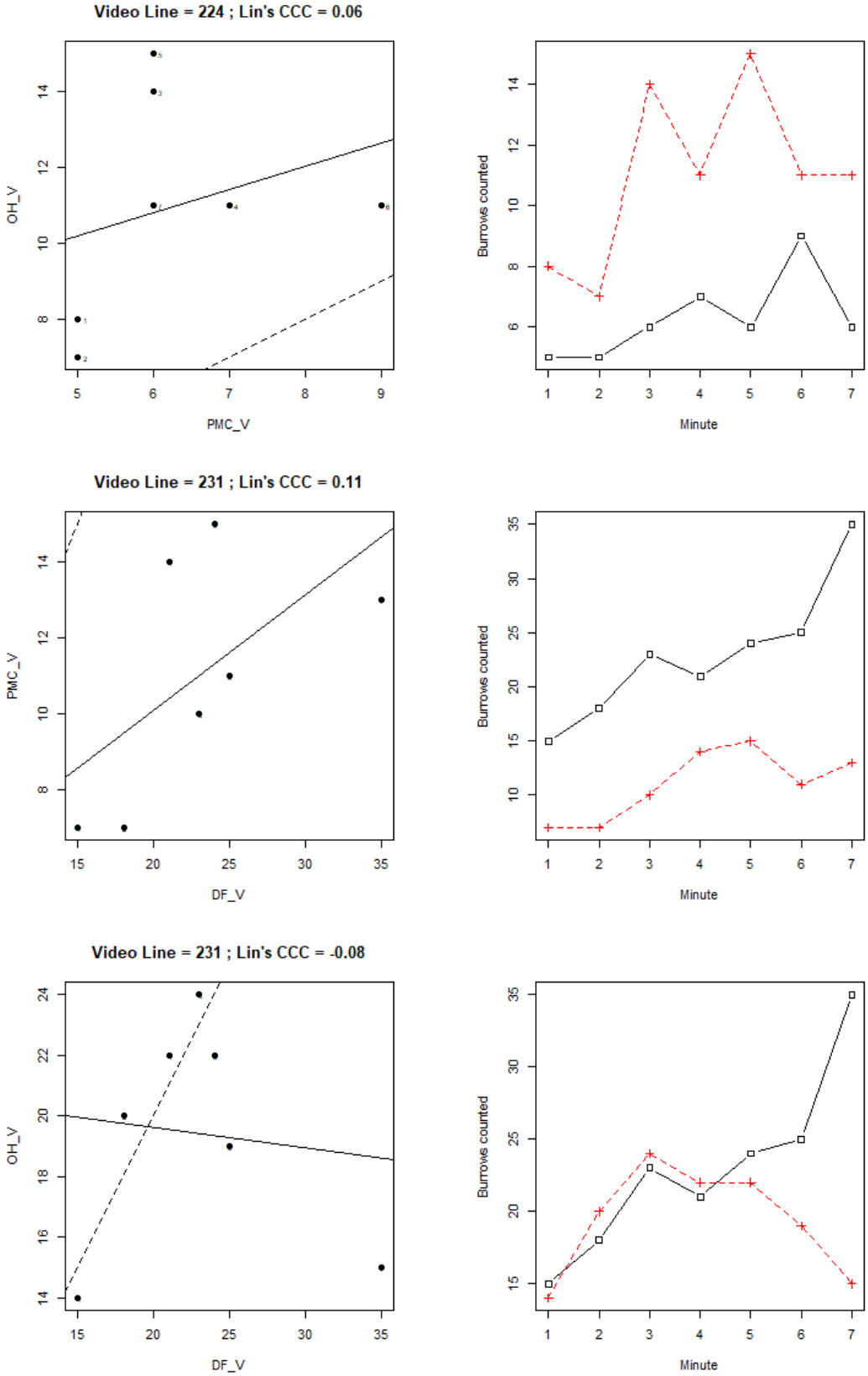




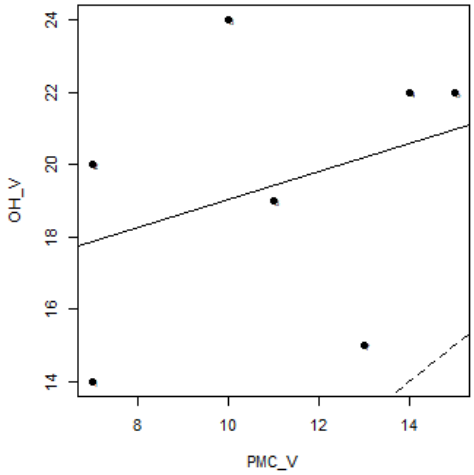
Video Line = 224 ; Lin's CCC = 0.5

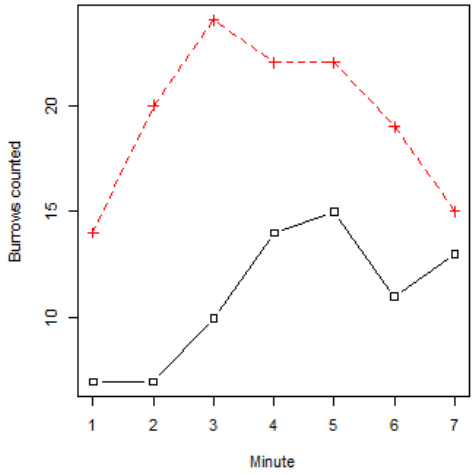




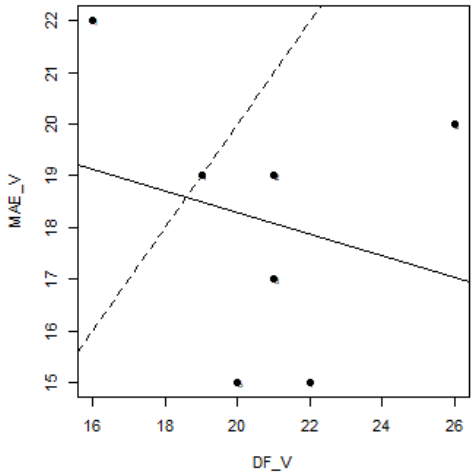

Video Line = 224 ; Lin's CCC = 0.06
OH_V
PMC_V
Burrows counted
Minute
Video Line = 231 ; Lin's CCC = 0.11
PMC_V
DF_V
Burrows counted
Minute
Video Line = 231 ; Lin's CCC = -0.08
OH_V
DF_V
Burrows counted
Minute

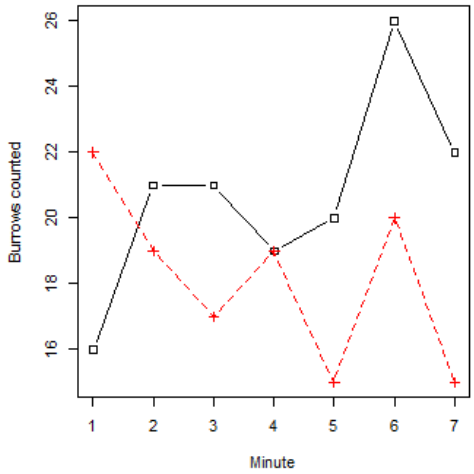
Video Line = 231 ; Lin's CCC = 0.07



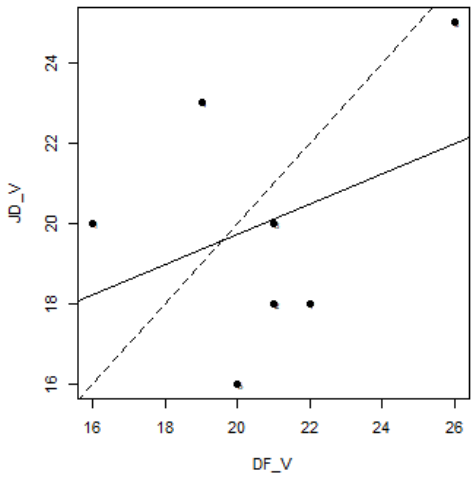


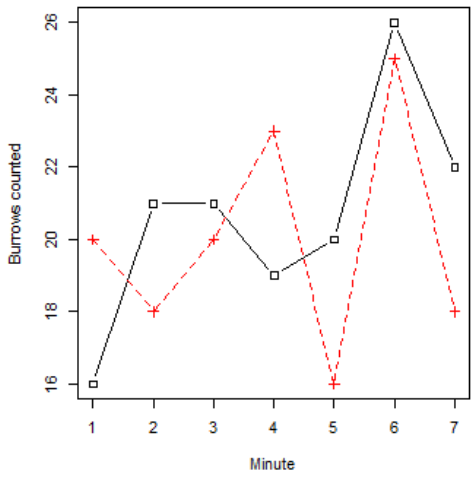
Video Line = 232 ; Lin's CCC = -0.16

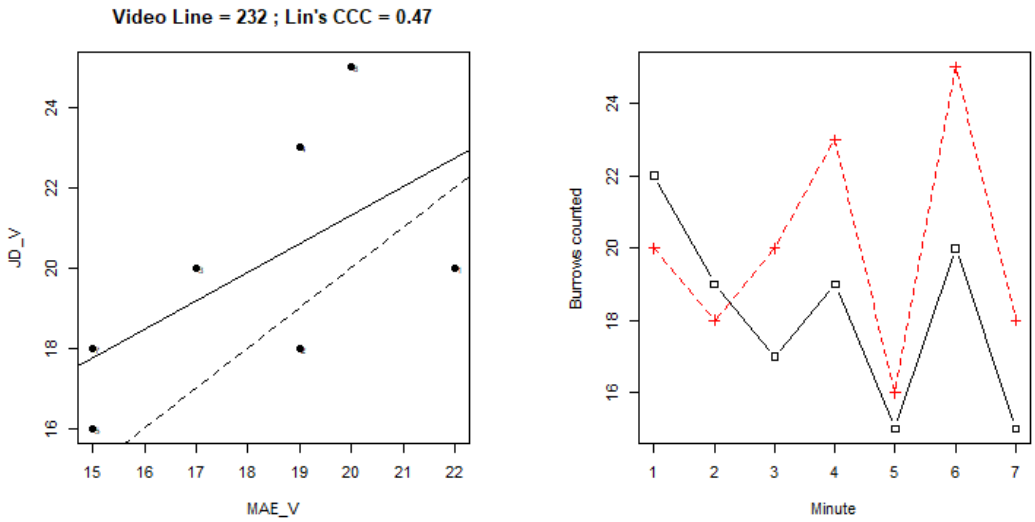


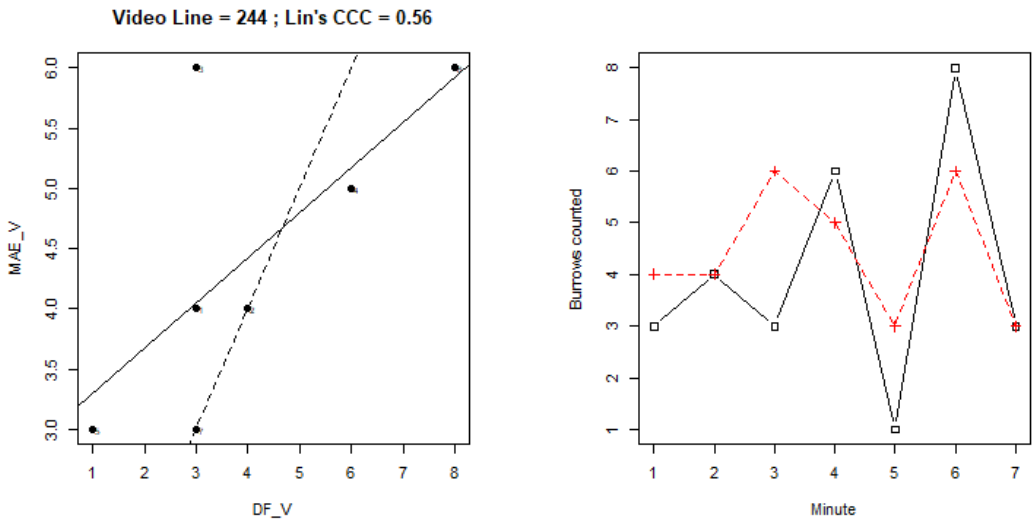


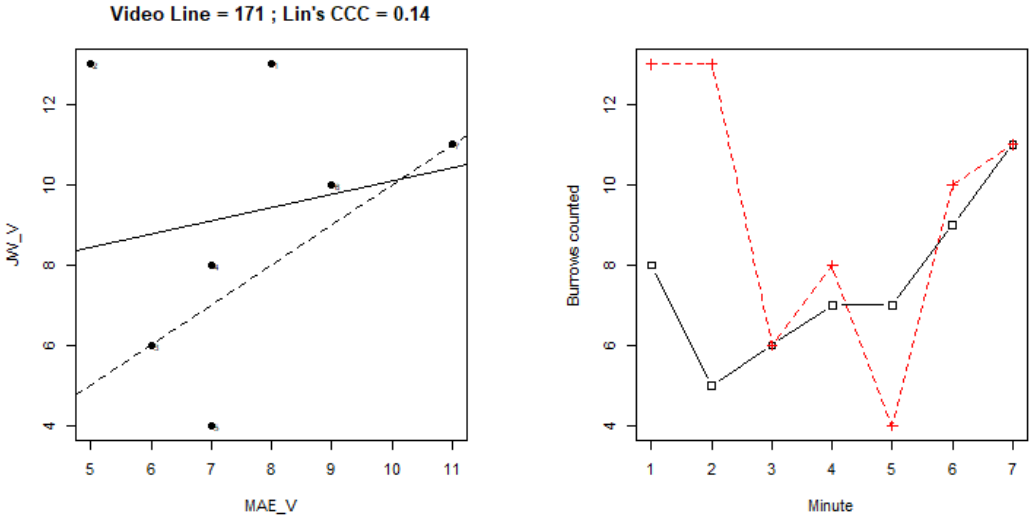
Video Line = 232 ; Lin's CCC = 0.36

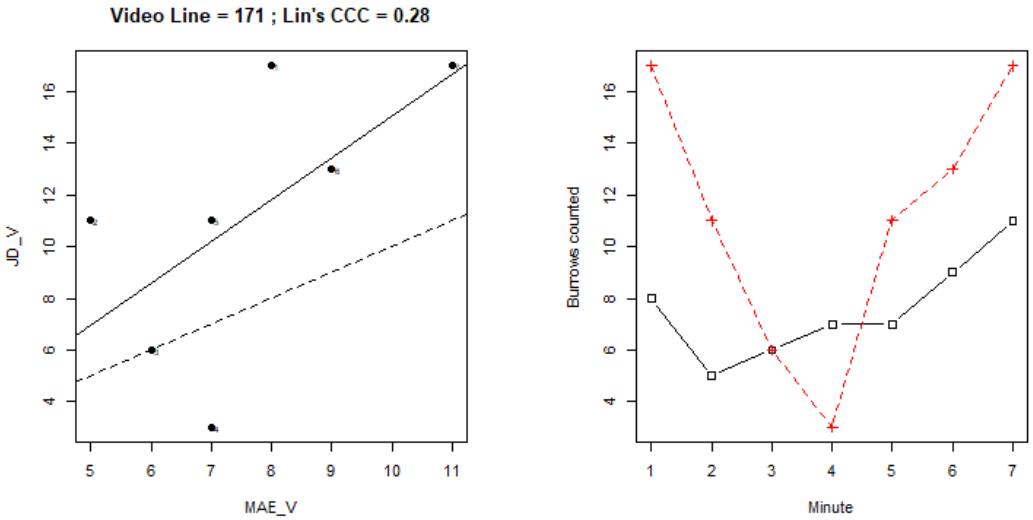


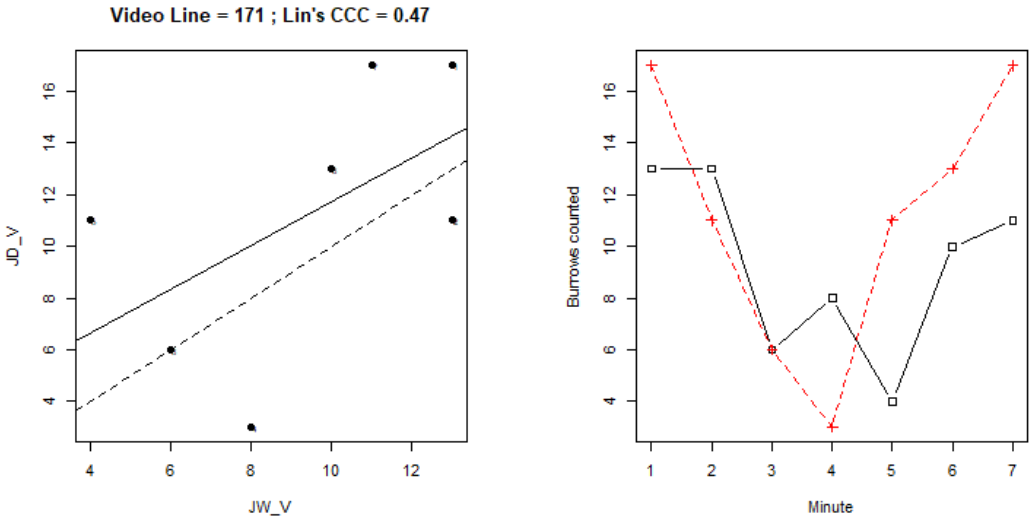


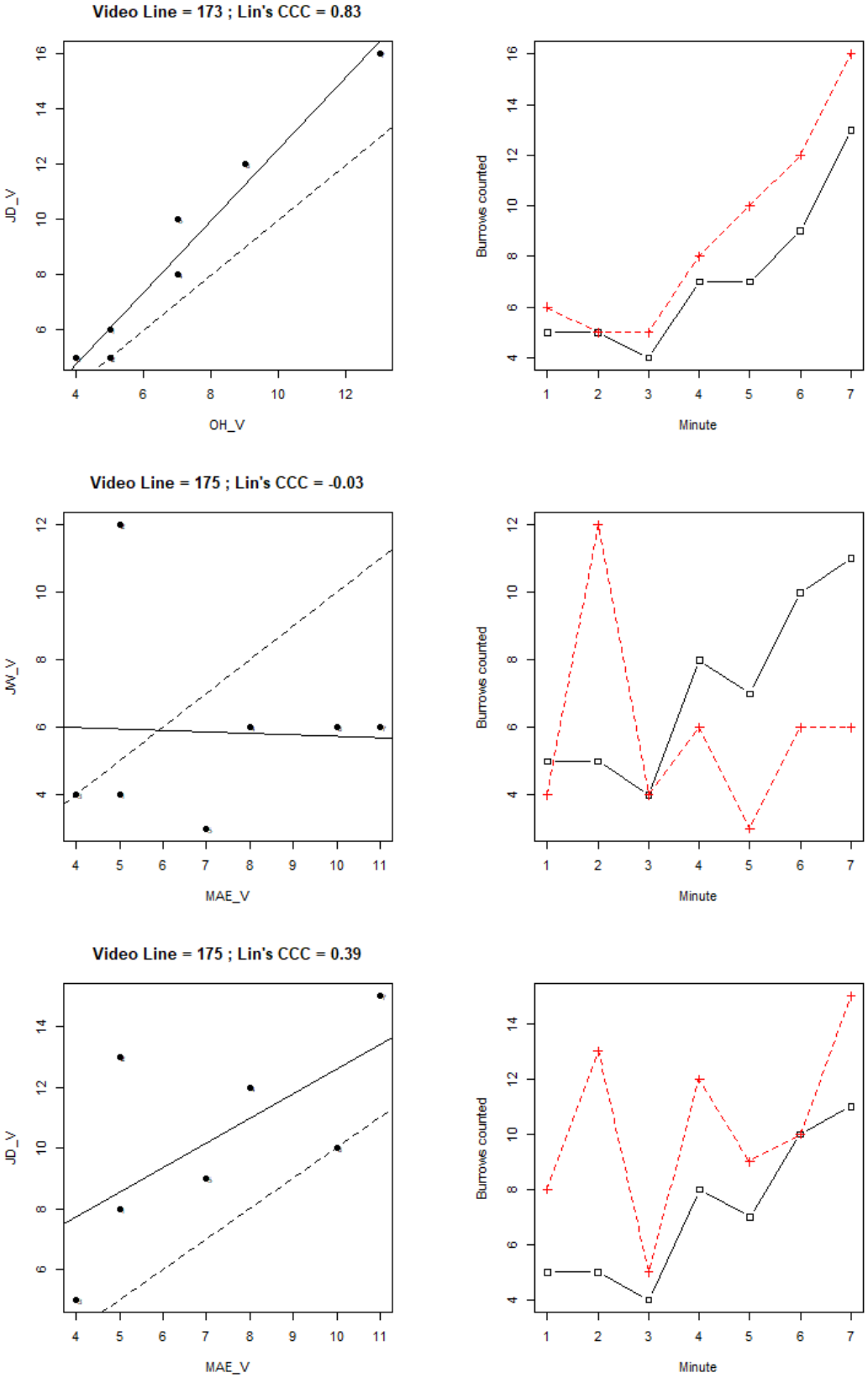

Video Line = 232 ; Lin's CCC = 0.47
JD_V
MAE_V
Burrows counted
Minute


Video Line = 244 ; Lin's CCC = 0.56
MAE_V
DF_V
Burrows counted
Minute

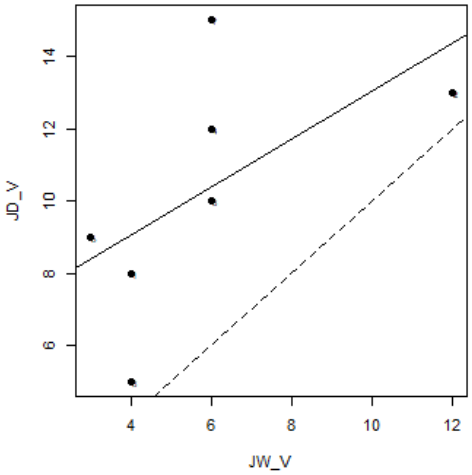

Video Line = 171 ; Lin's CCC = 0.14
JW_V
MAE_V
Burrows counted
Minute

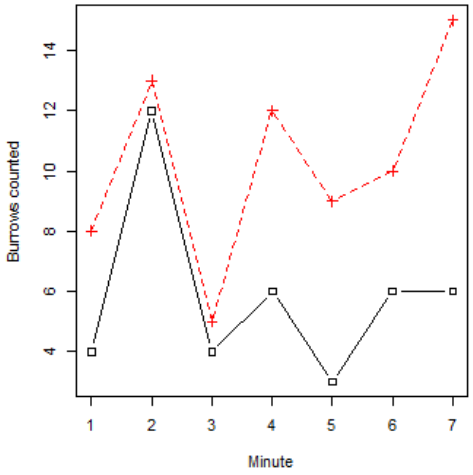

Video Line = 171 ; Lin's CCC = 0.28
JD_V
MAE_V
Burrows counted
Minute


Video Line = 171 ; Lin's CCC = 0.47
JD_V
JW_V
Burrows counted
Minute

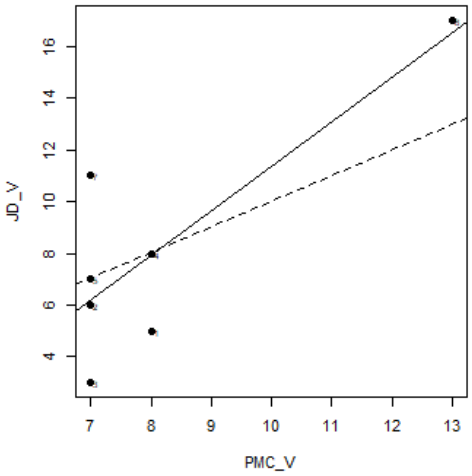

Video Line = 173 ; Lin's CCC = 0.83
JD_V
OH_V
Burrows counted
Minute
Video Line = 175 ; Lin's CCC = -0.03
JW_V
MAE_V
Burrows counted
Minute
Video Line = 175 ; Lin's CCC = 0.39
JD_V
MAE_V
Burrows counted
Minute

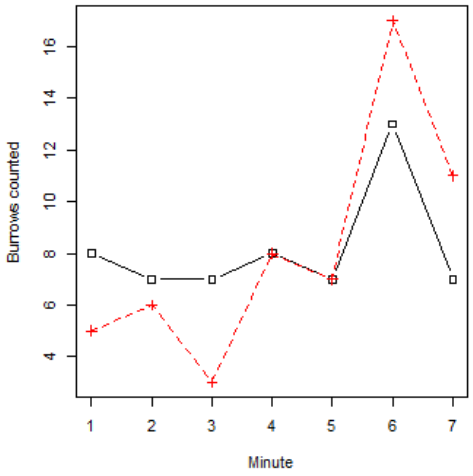
Video Line = 175 ; Lin's CCC = 0.27



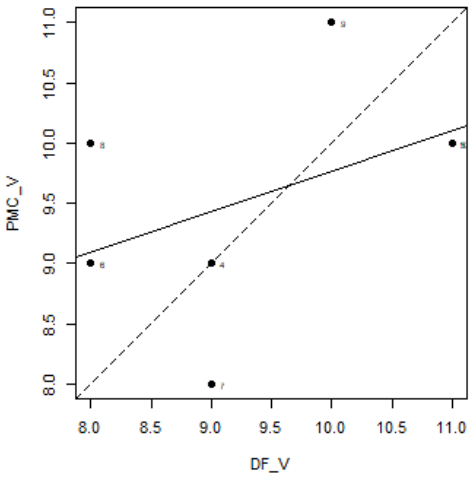


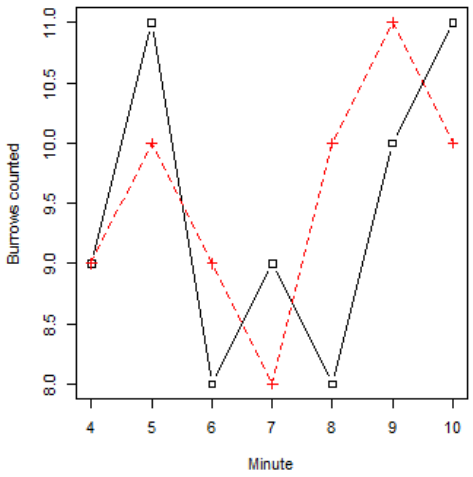
Video Line = 178 ; Lin's CCC = 0.63

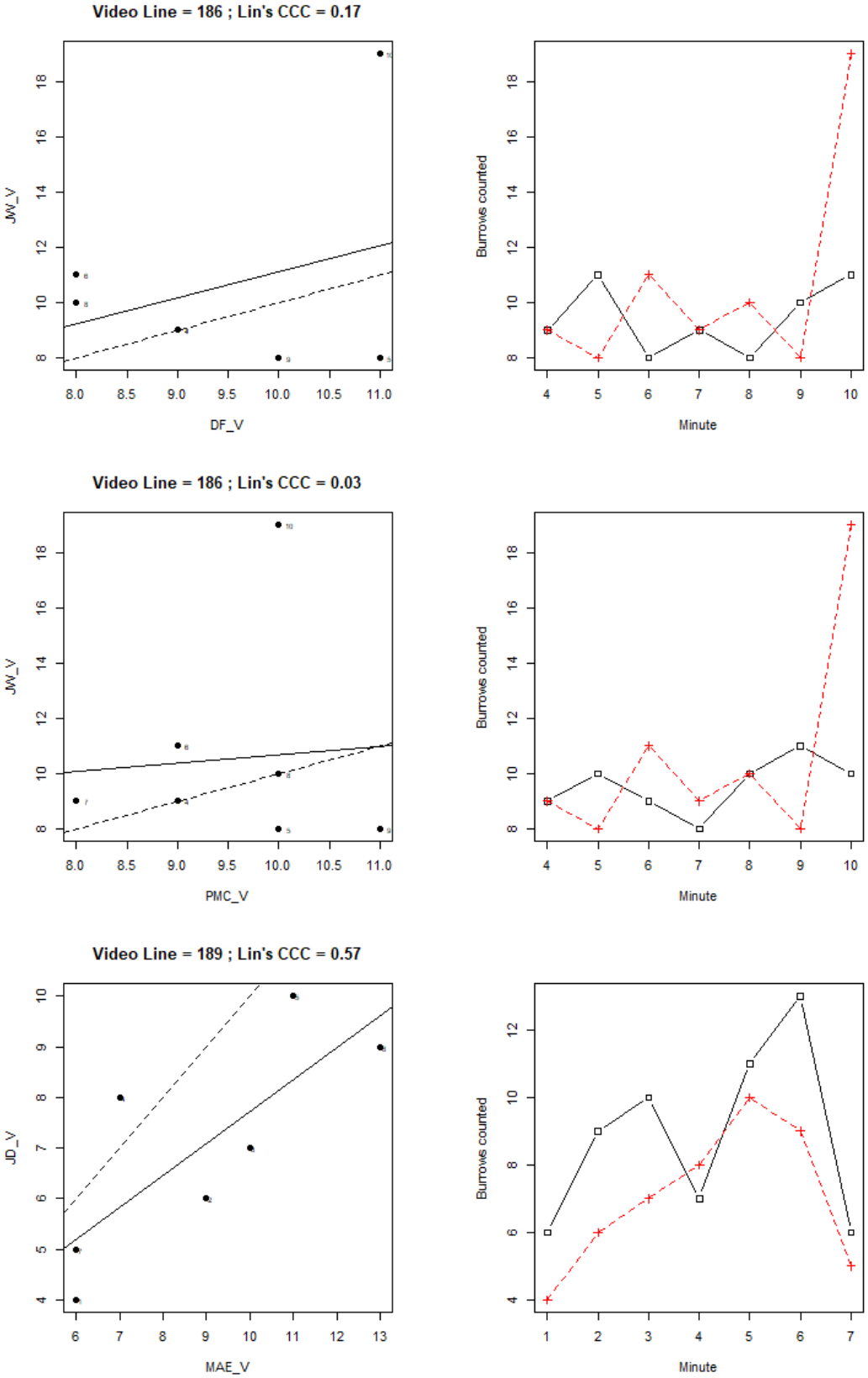


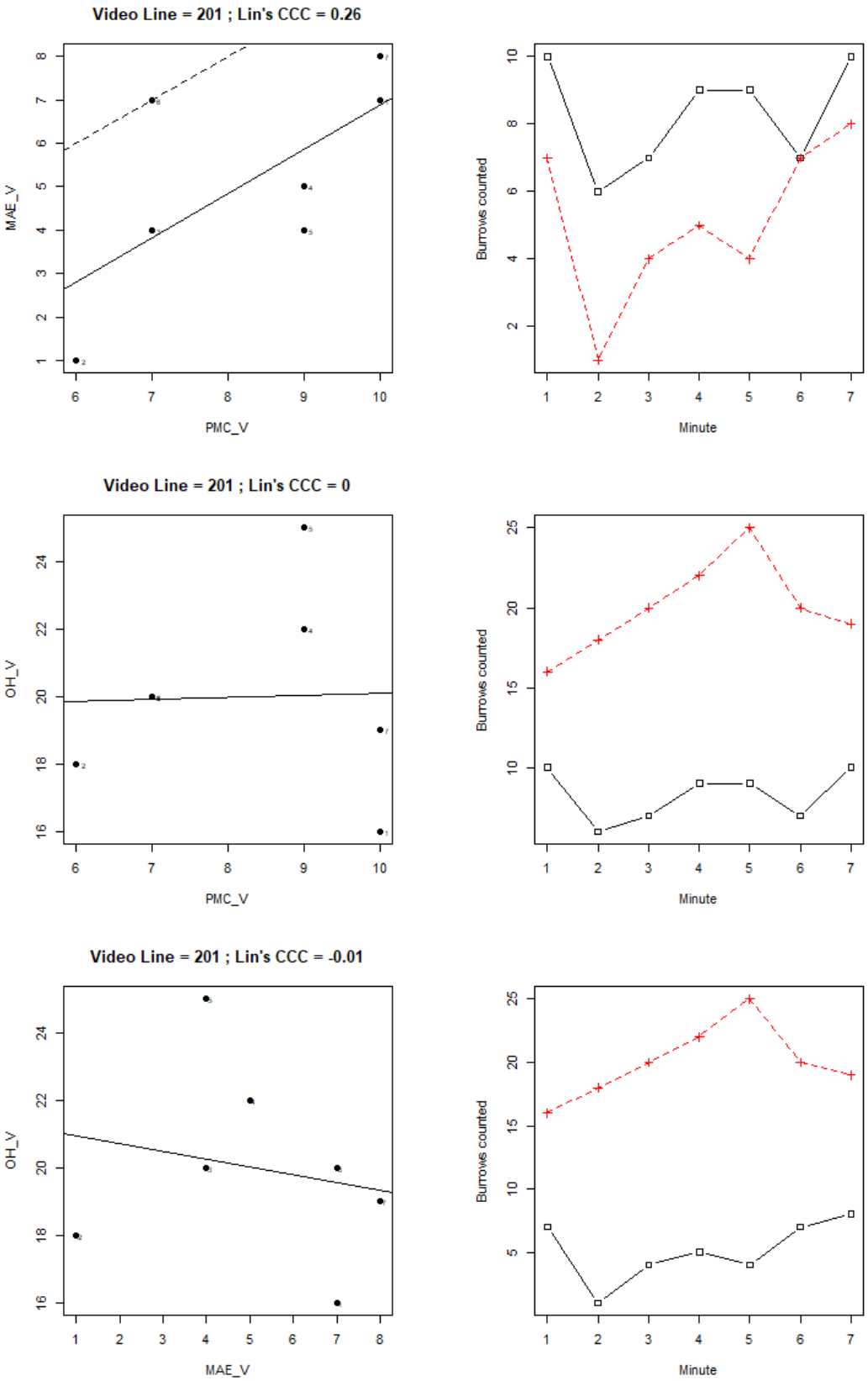


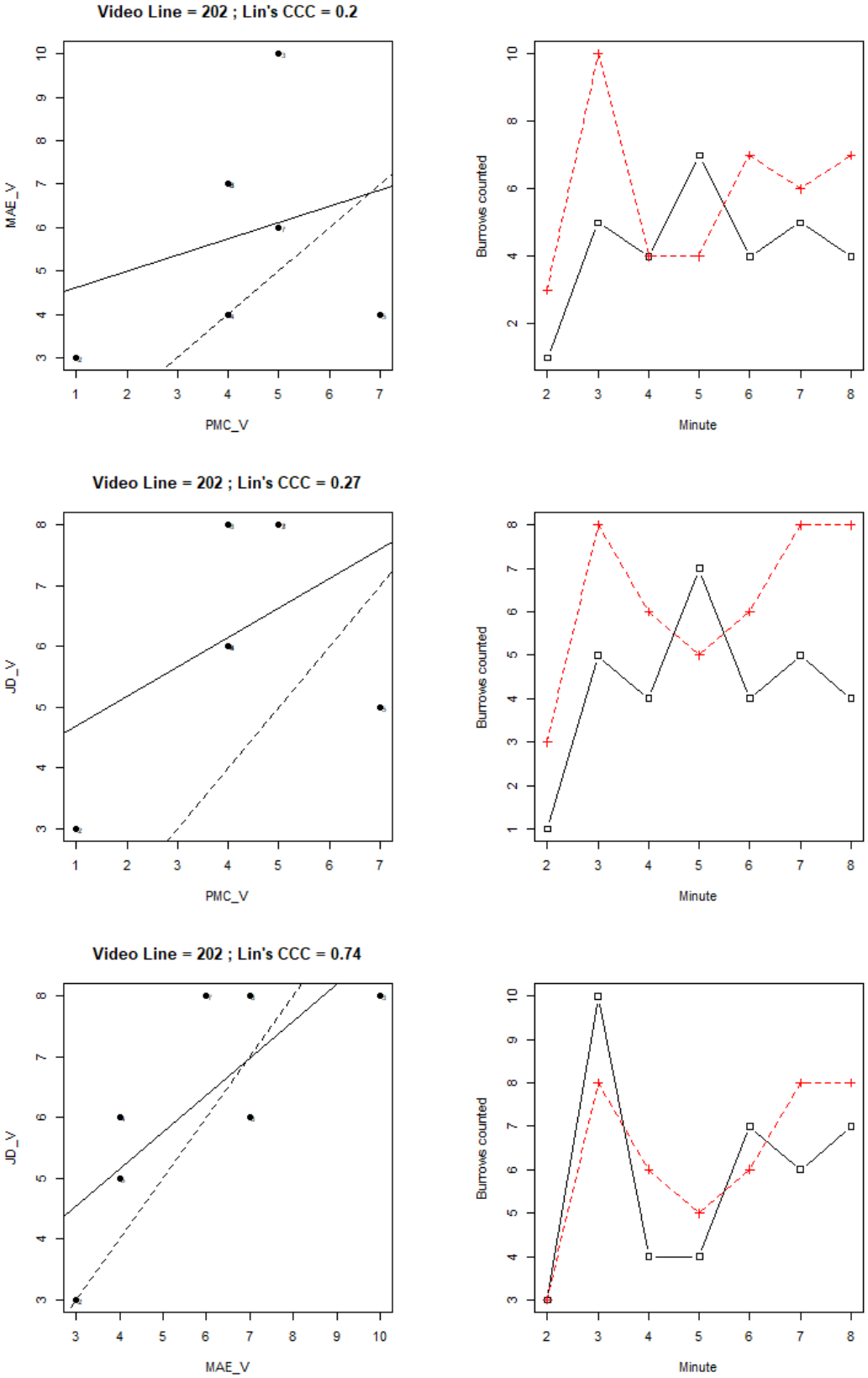
Video Line = 186 ; Lin's CCC = 0.42

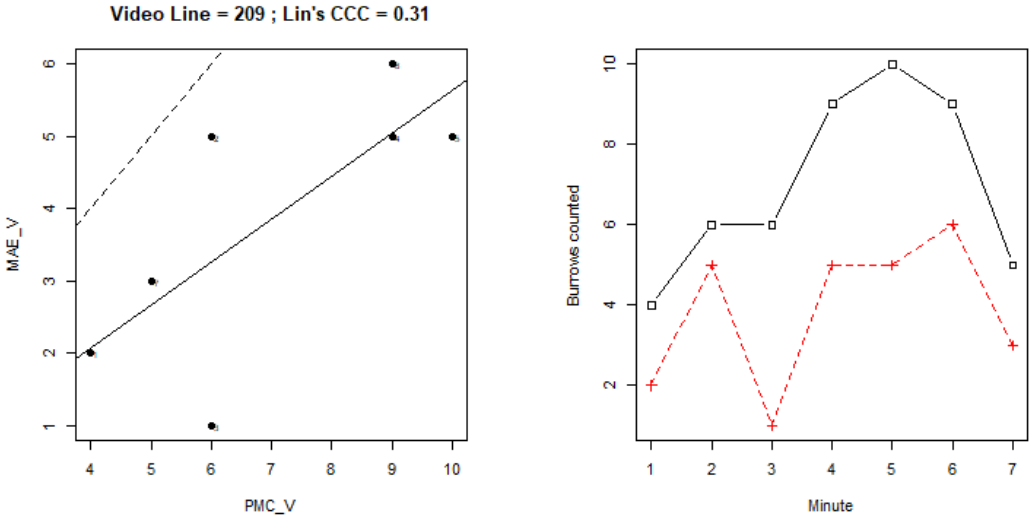


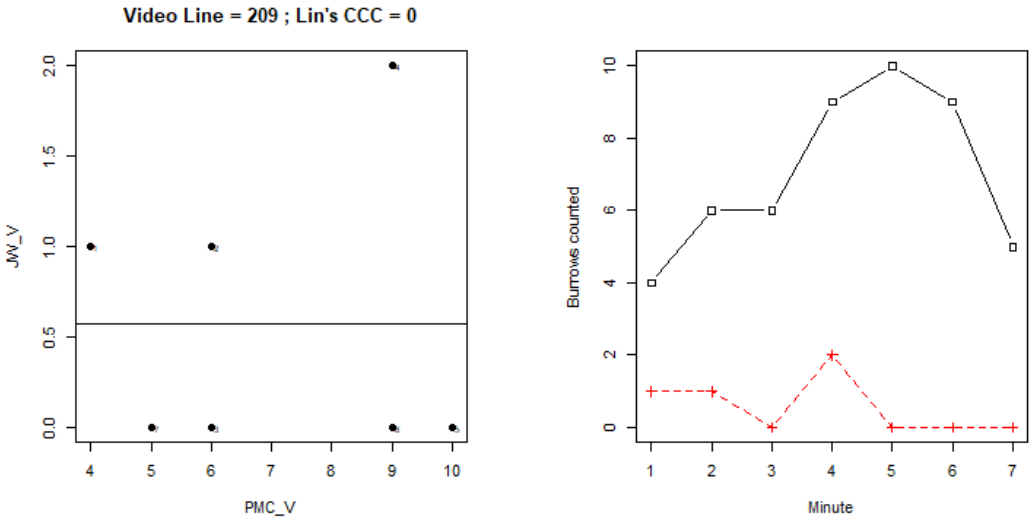


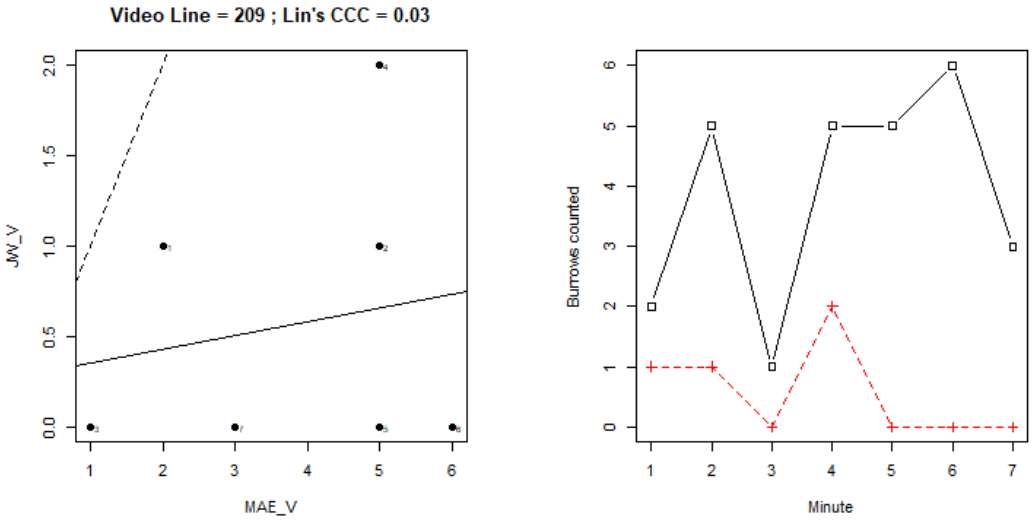

Video Line = 186 ; Lin's CCC = 0.17
JW_V
DF_V
Burrows counted
Minute
Video Line = 186 ; Lin's CCC = 0.03
JW_V
PMC_V
Burrows counted
Minute
Video Line = 189 ; Lin's CCC = 0.57
JD_V
MAE_V
Burrows counted
Minute

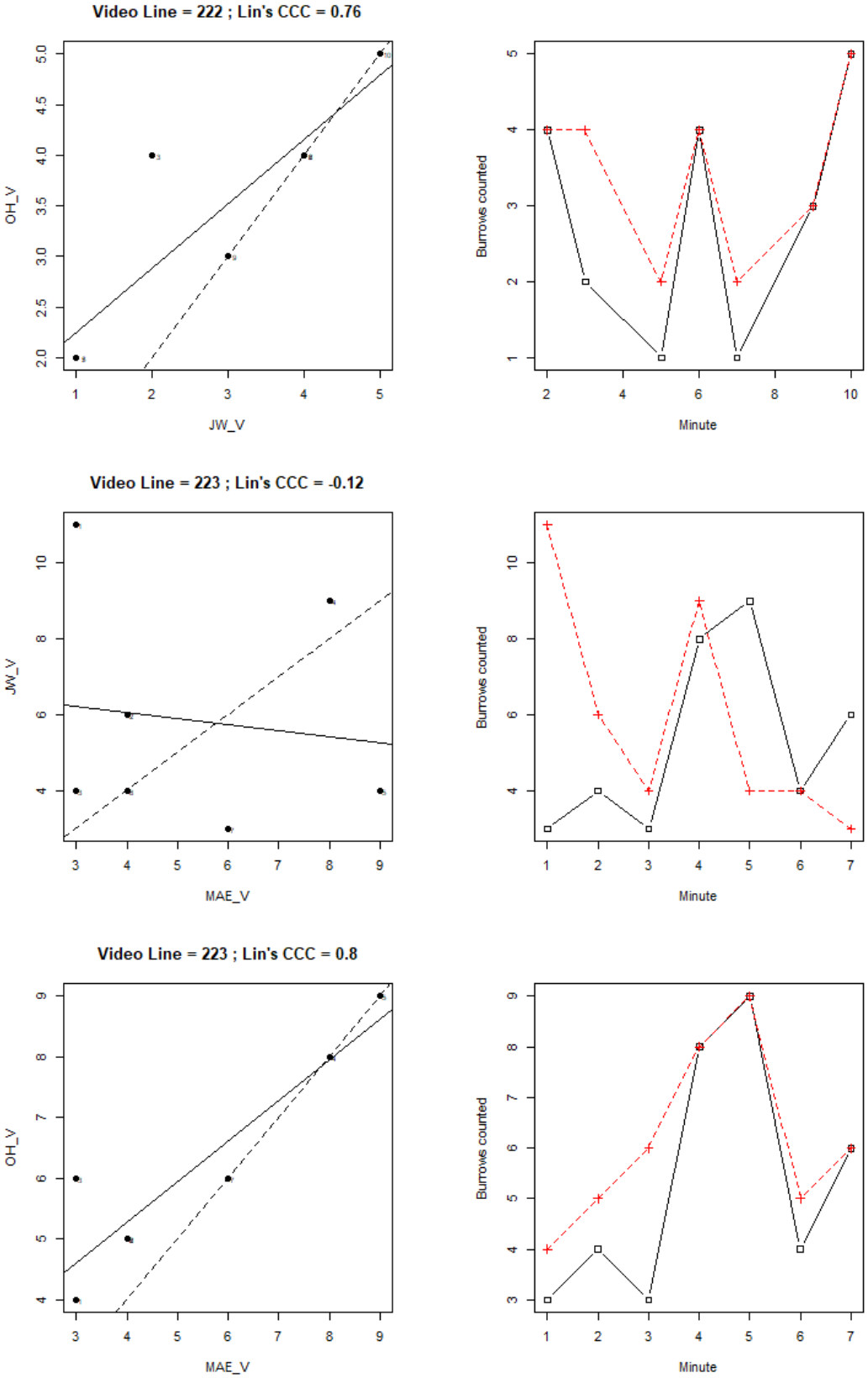

Video Line = 201 ; Lin's CCC = 0.26
MAE_V
PMC_V
Burrows counted
Minute
Video Line = 201 ; Lin's CCC = 0
OH_V
PMC_V
Burrows counted
Minute
Video Line = 201 ; Lin's CCC = -0.01
OH_V
MAE_V
Burrows counted
Minute


Video Line = 202 ; Lin's CCC = 0.2
MAE_V
PMC_V
Burrows counted
Minute
Video Line = 202 ; Lin's CCC = 0.27
JD_V
PMC_V
Burrows counted
Minute
Video Line = 202 ; Lin's CCC = 0.74
JD_V
MAE_V
Burrows counted
Minute

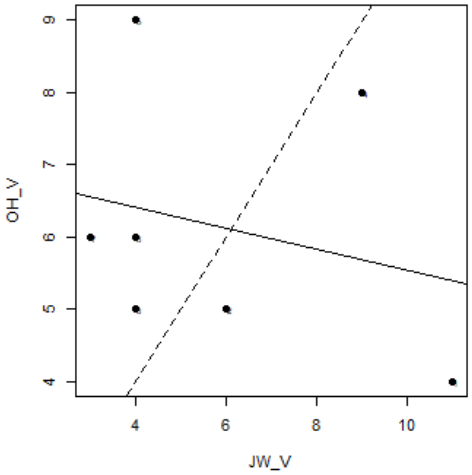

Video Line = 209 ; Lin's CCC = 0.31
MAE_V
PMC_V
Burrows counted
Minute

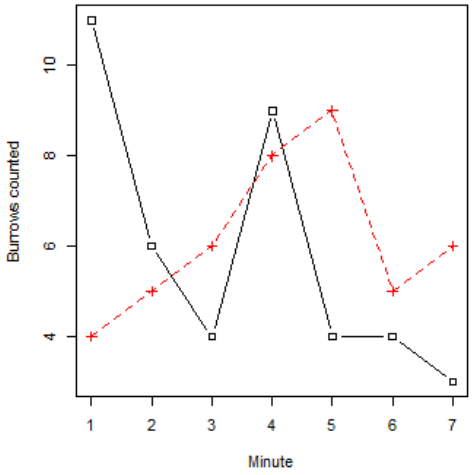

Video Line = 209 ; Lin's CCC = 0
JW_V
PMC_V
Burrows counted
Minute


Video Line = 209 ; Lin's CCC = 0.03
JW_V
MAE_V
Burrows counted
Minute

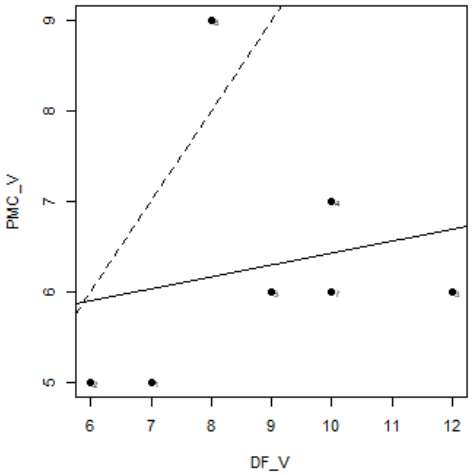

Video Line = 222 ; Lin's CCC = 0.76
OH_V
JW_V
Burrows counted
Minute
Video Line = 223 ; Lin's CCC = -0.12
JW_V
MAE_V
Burrows counted
Minute
Video Line = 223 ; Lin's CCC = 0.8
OH_V
MAE_V
Burrows counted
Minute

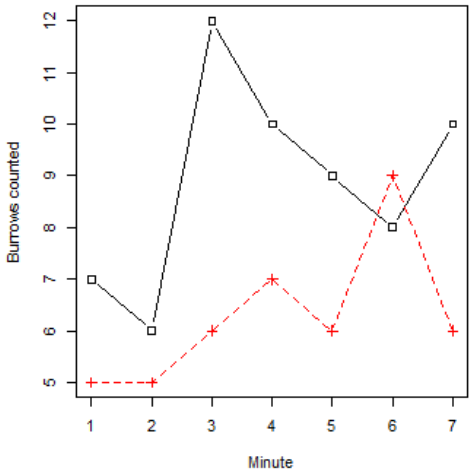
Video Line = 223 ; Lin's CCC = -0.21



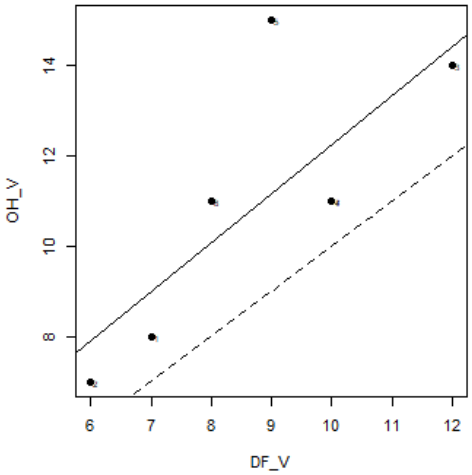


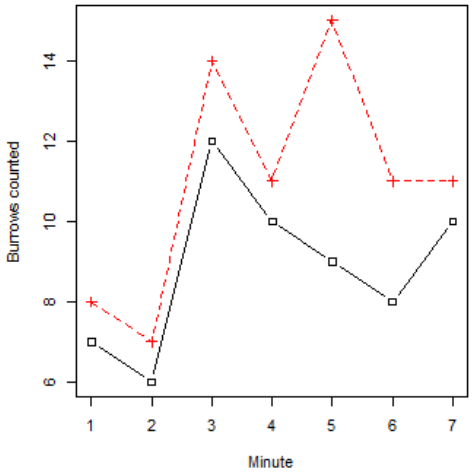
Video Line = 224 ; Lin's CCC = 0.08

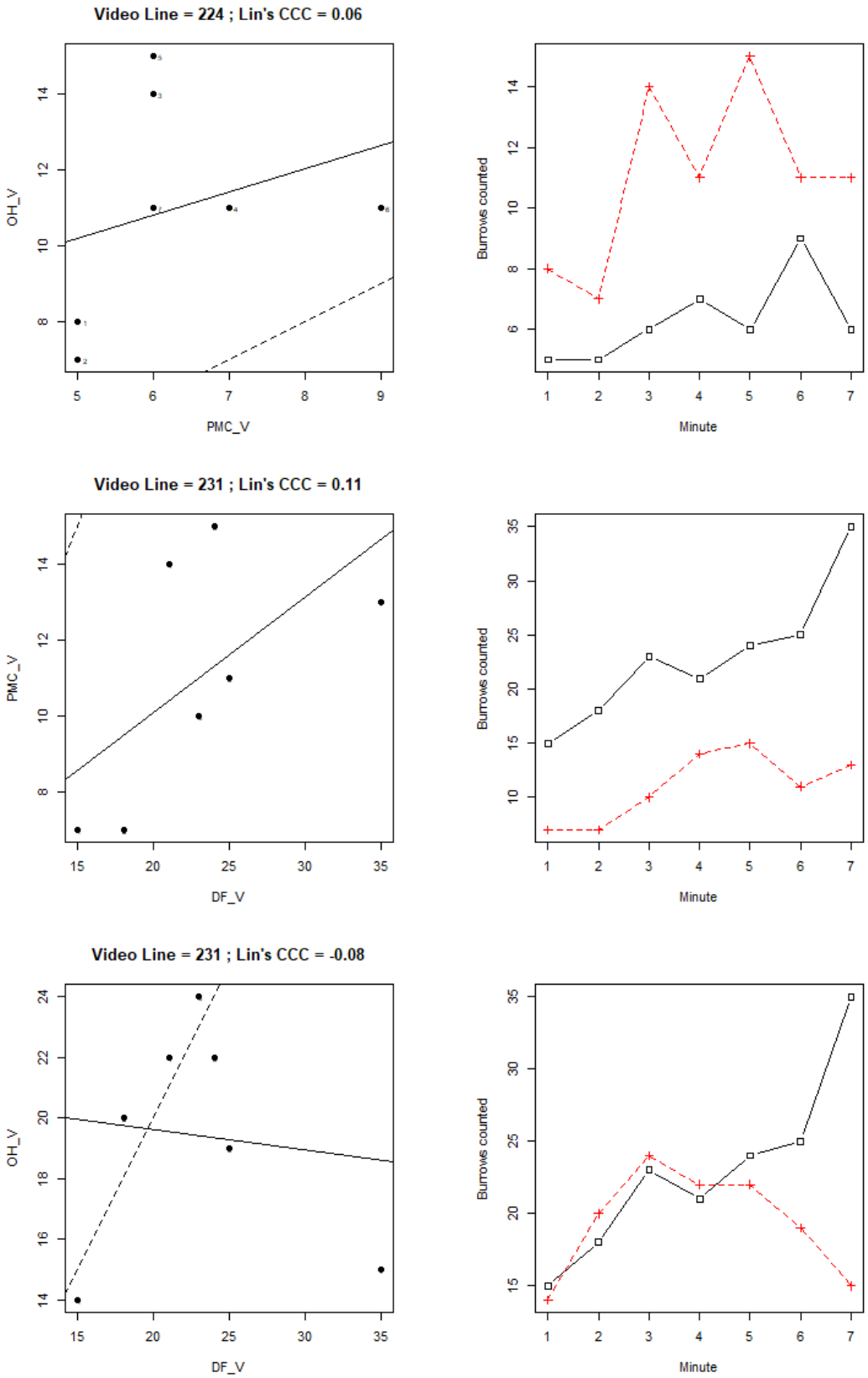




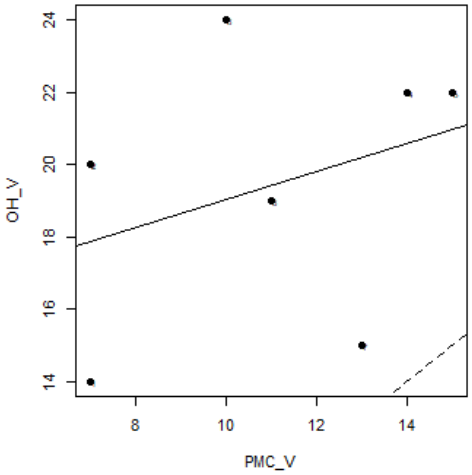
Video Line = 224 ; Lin's CCC = 0.5

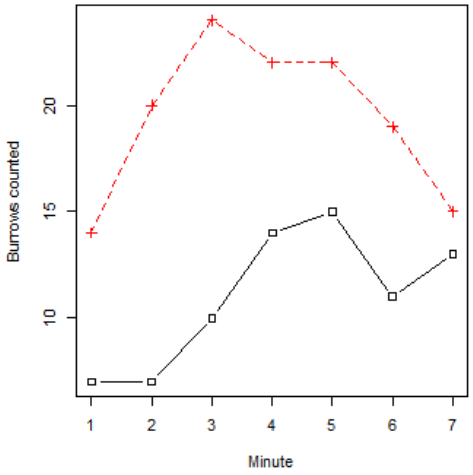




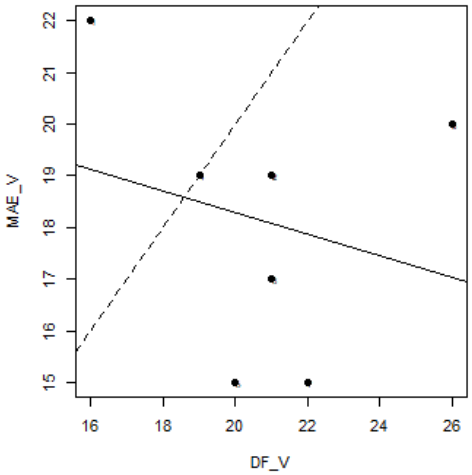

Video Line = 224 ; Lin's CCC = 0.06
OH_V
PMC_V
Burrows counted
Minute
Video Line = 231 ; Lin's CCC = 0.11
PMC_V
DF_V
Burrows counted
Minute
Video Line = 231 ; Lin's CCC = -0.08
OH_V
DF_V
Burrows counted
Minute

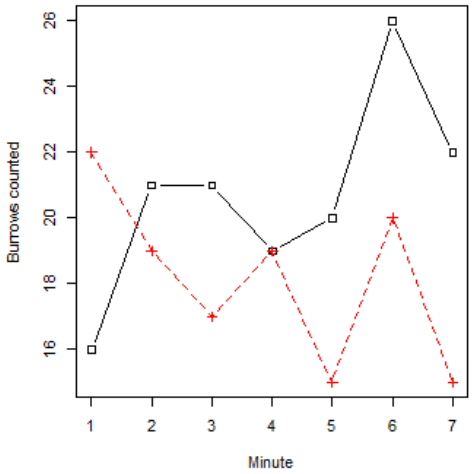
Video Line = 231 ; Lin's CCC = 0.07



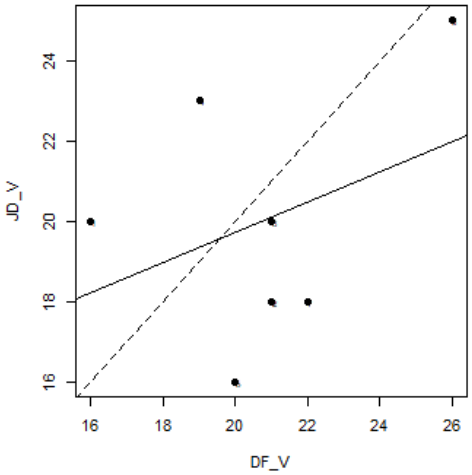


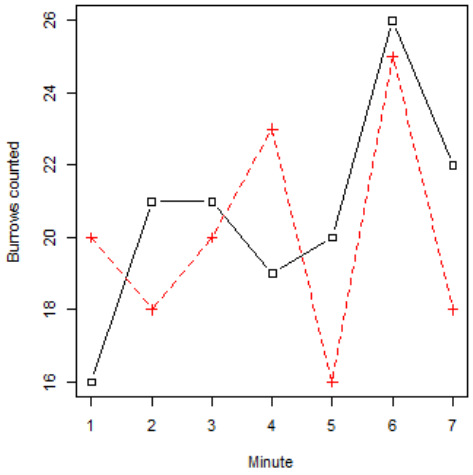
Video Line = 232 ; Lin's CCC = -0.16

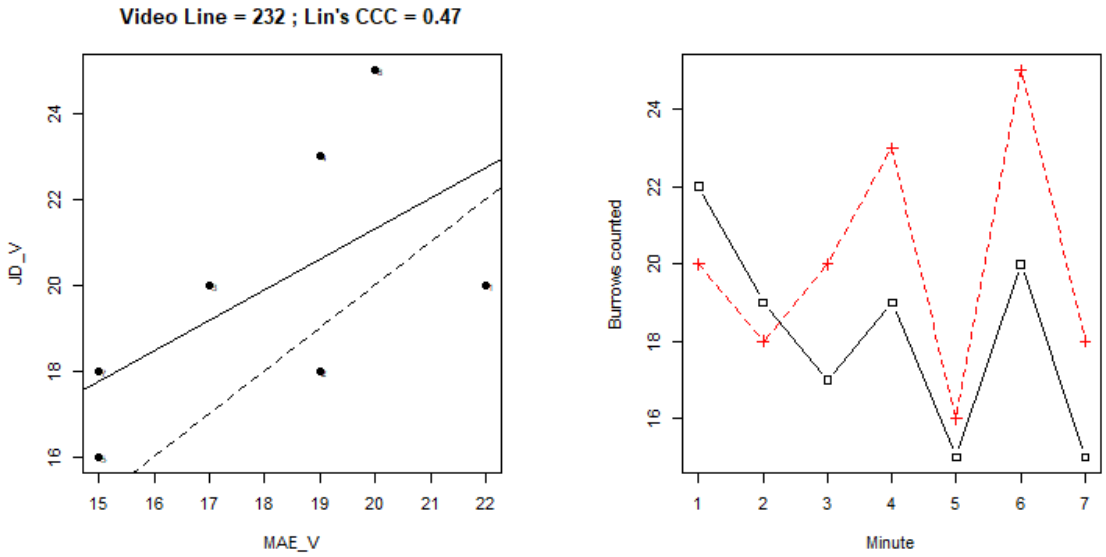


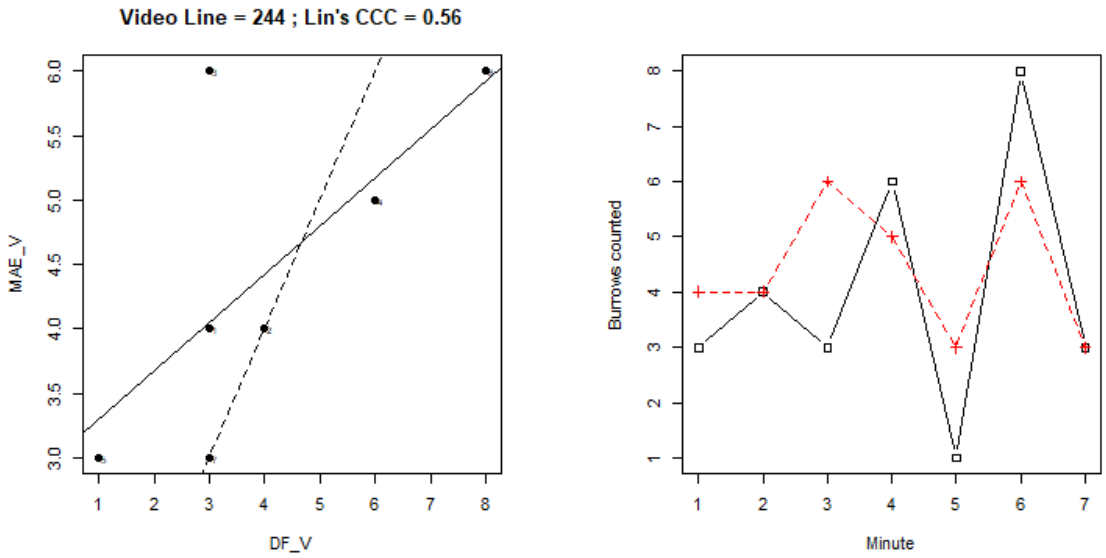


Video Line = 232 ; Lin's CCC = 0.36






Video Line = 232 ; Lin's CCC = 0.47
JD_V
MAE_V
Burrows counted
Minute


Video Line = 244 ; Lin's CCC = 0.56
MAE_V
DF_V
Burrows counted
Minute

2.6 Lin's CCC results

- 1/16 station was below the cutoff counts, where Lin's cannot be used on stations with very low counts
- 5/16 stations passed LINS CCC threshold (0.5) with the first 2 counters.
- 10/16 stations required a third review where 7 of these stations all 3 reviewers data were used to calculate final density. This is the standard practice on UWTV surveys by the Marine Institute.

Now we will remove the 3rd reviewer from the other stations (3 stations).

```
## stn 202 PMC_V 15 stn 223 JW_V 35 stn 224 PMC_V 15

Recounts1 <- Recounts[-which(Recounts$Video_Line_Name == 202 & Recoun
ts$VideoOperatorID ==
    15), ]
Recounts1 <- Recounts1[-which(Recounts1$Video_Line_Name == 223 & Reco
unts1$VideoOperatorID ==
    35), ]
Recounts1 <- Recounts1[-which(Recounts1$Video_Line_Name == 224 & Reco
unts1$VideoOperatorID ==
    15), ]
```

2.7 Comparison by station: 2016 original counts vs. validation counts

```
# calculate average count per station for historical review
rec.1 <- Recounts1 %>% group_by(Video_Line_Name, Minute) %>% summaris
e(ct = mean(BurrowCount))
val.data <- rec.1 %>% group_by(Video_Line_Name) %>% summarise(av.coun
t = sum(ct))
val.data$method <- "review"

# next extract sea counts (original data from 2016)
orig.data <- subset(rec, !VideoOperatorID %in% c(12, 15, 34, 35, 36,
37))

orig.minute <- with(orig.data, aggregate(BurrowCount, by = list(Minut
e,
    Video_Line_Name), FUN = mean))
names(orig.minute) <- c("Minute", "Video_Line_Name", "ct")
orig.data <- with(orig.minute, aggregate(ct, by = list(Video_Line_Nam
e),
    FUN = sum))
names(orig.data) <- c("Video_Line_Name", "av.count")
orig.data$method <- "original"

final2016 <- rbind(orig.data, val.data)

# merge both datasets
wide <- merge(orig.data, val.data, by = "Video_Line_Name")
wide <- wide[, -c(3, 5)]
wide <- rbind(wide, c("Total", colSums(wide)[2:3]))
names(wide) <- c("stn", "orig.count", "valid.count")
wide[, 2] <- as.numeric(wide[, 2])
wide[, 3] <- as.numeric(wide[, 3])
wide$perc.change <- 100 * with(wide, (valid.count/orig.count) - 1)
```

```
knitr::kable(wide[, 1:4], caption = paste0("2016 FU20-21 UWTV Origina
l survey counts,",
    " Validation review counts and difference in percentage for each
of the",
    " Reviewed stations and in total"))
```

Table 4.2016 FU20-21 UWTV Original survey counts, Validation review counts and difference in percentage for each of the Reviewed stations and in total

stn	orig.count	valid.count	perc.change
171	122.0	65.3333333	-46.4480874
173	18.0	56.0000000	211.1111111
175	62.0	54.3333333	-12.3655914
178	34.5	57.0000000	65.2173913
186	55.0	69.0000000	25.4545455
189	45.0	55.5000000	23.3333333
196	15.5	8.3333333	-46.2365591
201	55.5	78.0000000	40.5405405
202	19.0	42.5000000	123.6842105
209	51.5	26.6666667	-48.2200647
222	52.5	22.0000000	-58.0952381
223	68.0	40.0000000	-41.1764706
224	94.0	69.5000000	-26.0638298
231	72.0	124.6666667	73.1481481
232	119.5	137.3333333	14.9232915
244	17.0	29.5000000	73.5294118
Total	901.0	935.6666667	3.8475768

```
ggplot(final2016, aes(x = as.factor(Video_Line_Name), y = av.count, f
ill = method,
    col = method)) + geom_bar(width = 0.8, stat = "identity", positio
n = position_dodge()) +
    xlab("Station ID") + ylab("count") + theme_bw()
```

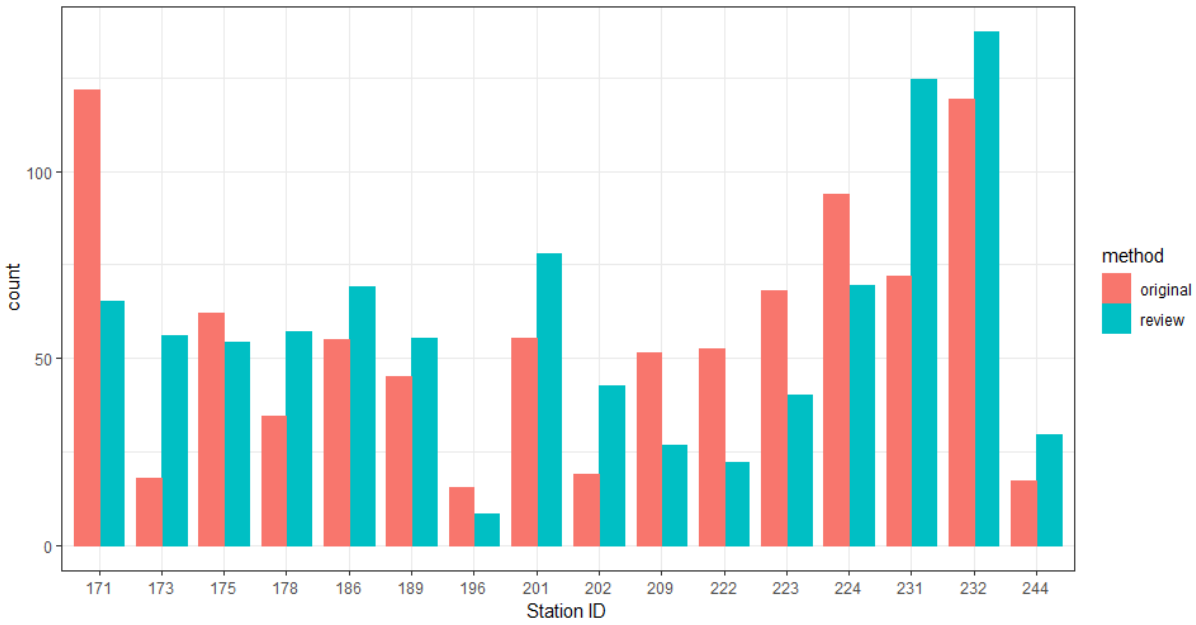


Figure 2: Bar plot showing 2016 original counts and the validation counts

2.8 Violin plot of the 2016 original counts and the validation counts

```
final2016 <- cbind(final2016, wide[-nrow(wide),])

## Warning in data.frame(..., check.names = FALSE): row names were fo
und from
## a short variable and have been discarded

ggplot(final2016,aes(x=as.factor(method),y=av.count))+
  geom_violin(aes(group=method,colour=method,fill=method),alpha=0.5,
              kernel="rectangular")+           # passes to stat_densi
ty, makes violin rectangular
  geom_boxplot(aes(group=method), width=.2)+
  stat_summary(fun.y=mean, geom="line", colour="blue", aes(group=1))
+
  xlab("method")+
  ylab("av.count")+
  theme_bw()+
  theme(legend.position = "none")
```

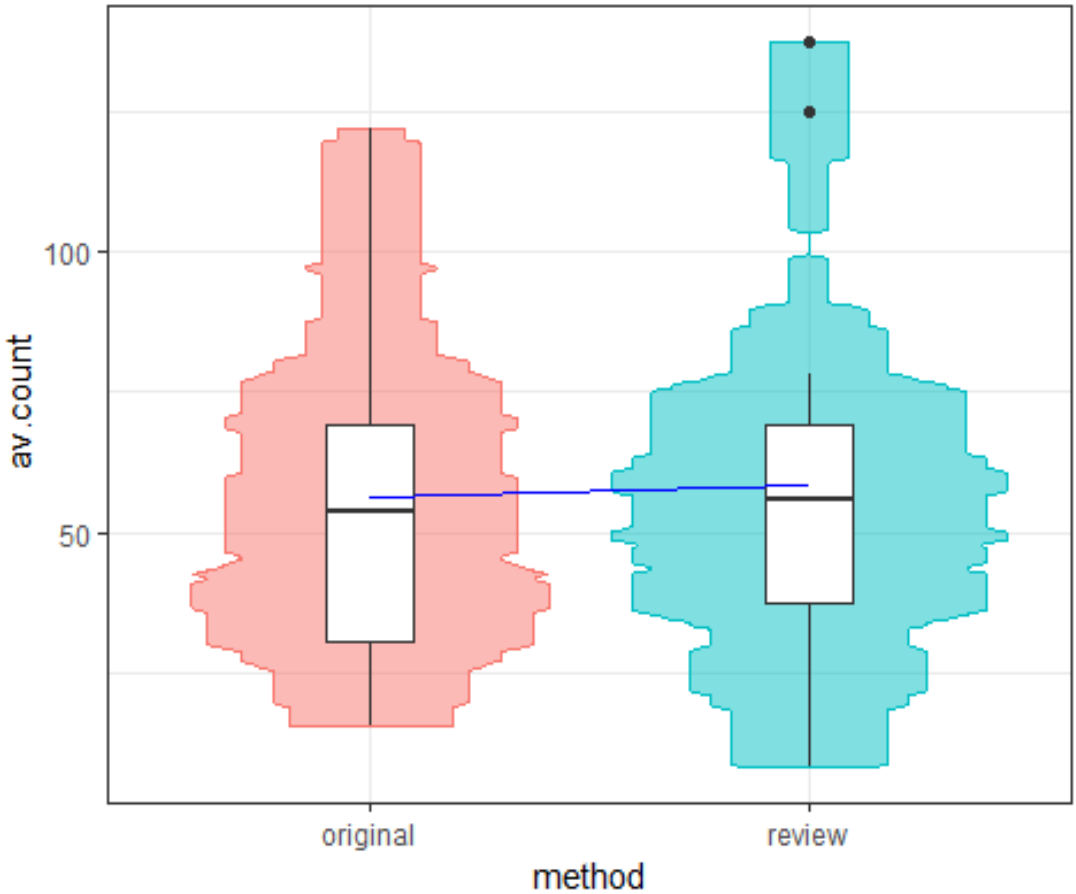


Figure 3. Violin and box plot of counts distributions of 2016 original counts and validation counts. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers

3 2016: KRIGING

We load the data and select the review counts for the 16 reviewed stations in 2018. We created the local access queries to generate the final data for input. We checked the local queries sql queries and R queries to make sure they do the same.

3.1. Previous step for getting the coordinates of the original stations in 2016

```
## Code to connect to live UWTV_SURVEY database on MI Network VMFSSSQ
L02
channel <- odbcDriverConnect("Driver=SQL Server; Server=VMFSSSQL02; D
atabase=UWTV_Surveys; ")
nep.all <- sqlQuery(channel, "select * from dbo.Summary_FullWorkUp_US
BL_Vw")
close(channel)

nep <- subset(nep.all, Year == 2016 & Ground == "Labadie")
nep1 <- nep[, c(2, 5, 12, 13)]  # we create nep1 to join later to the
validation counts
nep1$StationNumber <- as.numeric(as.character(nep1$StationNumber))
```

3.2 Run the queries in the local survey database to calculate final data for kriging

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2016/Kriging")

# The database must be CLOSED to run the following queries
channel <- odbcConnectAccess(paste0("N:/Surveys/UWTV SURVEYS FU2022 C
ELTIC SEA/",
    "Historical review Labadie 2016/Final Data/", "NEPHROPS_MULTILOG_
CV16024_Labadie"))

# Query 1
StopTime <- sqlQuery(channel, "
SELECT Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoOpe
ratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime
FROM Recounts
GROUP BY Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoO
peratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime
HAVING (((Recounts.StopTime)>=#12/30/1899# And (Recounts.StopTime)<=#
12/30/1899 0:15:0#)
AND ((Recounts.StartTime)>=#12/30/1899# And (Recounts.StartTime)<=#12
/30/1899 0:15:0#));
         ")

# Query 2
sqlDrop(channel, "RecountNotUsuable")
sqlQuery(channel, "
SELECT Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoOpe
ratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime,
Recounts!StartTime-Recounts!StopTime AS DifferenceNumber,
Recounts!StartTime-Recounts!StopTime AS DifferenceTime INTO RecountNo
tUsuable
FROM Recounts
GROUP BY Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoO
peratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime,
Recounts!StartTime-Recounts!StopTime, Recounts!StartTime-Recounts!Sto
pTime
HAVING (((Recounts.StopTime)>=#12/30/1899# And (Recounts.StopTime)<=#
12/30/1899 0:15:0#)
AND ((Recounts.StartTime)>=#12/30/1899# And (Recounts.StartTime)<=#12
/30/1899 0:15:0#));
         ")
StopTime1min <- sqlFetch(channel, "RecountNotUsuable")

# Query 3
IdentifyUnusuables <- sqlQuery(channel, "
SELECT RecountNotUsuable.SurveyID, RecountNotUsuable.Video_Line_Name,
RecountNotUsuable.VideoOperatorID, RecountNotUsuable.Minute, RecountN
otUsuable.StopTime,
RecountNotUsuable.StartTime, RecountNotUsuable.DifferenceTime,
RecountNotUsuable.DifferenceNumber, IIf([DifferenceNumber]>=0.0003472
22222222222,1000)
AS Unusuable
FROM RecountNotUsuable;
         ")
```

```
# Query 4
sqlDrop(channel, "UnusuableRecountMinsTable")
sqlQuery(channel, "
SELECT [Qry3_IdentifyUnusuablesForRecounts].SurveyID,
[Qry3_IdentifyUnusuablesForRecounts].Video_Line_Name,
[Qry3_IdentifyUnusuablesForRecounts].Minute,
[Qry3_IdentifyUnusuablesForRecounts].Unusuable
INTO UnusuableRecountMinsTable
FROM [Qry3_IdentifyUnusuablesForRecounts]
WHERE ((([Qry3_IdentifyUnusuablesForRecounts].Unusuable) Like 1000))
GROUP BY [Qry3_IdentifyUnusuablesForRecounts].SurveyID,
[Qry3_IdentifyUnusuablesForRecounts].Video_Line_Name,
[Qry3_IdentifyUnusuablesForRecounts].Minute, [Qry3_IdentifyUnusuables
ForRecounts].Unusuable;
         ")
MakeTable <- sqlFetch(channel, "UnusuableRecountMinsTable")

# Query 5
sqlDrop(channel, "Recounts-Clean")
sqlQuery(channel, "
SELECT Recounts.RecountID, Recounts.Video_Line_Name, Recounts.SurveyI
D,
Recounts.VideoOperatorID, Recounts.Minute, Recounts.BurrowCount,
Recounts.NephropsIn, Recounts.NephropsOut, Recounts.StopTime,
Recounts.StartTime, UnusuableRecountMinsTable.Unusuable INTO [Recount
s-Clean]
FROM Recounts LEFT JOIN UnusuableRecountMinsTable ON
(Recounts.Minute = UnusuableRecountMinsTable.Minute) AND
(Recounts.SurveyID = UnusuableRecountMinsTable.SurveyID) AND
(Recounts.Video_Line_Name = UnusuableRecountMinsTable.Video_Line_Name
)
GROUP BY Recounts.RecountID, Recounts.Video_Line_Name, Recounts.Surve
yID,
Recounts.VideoOperatorID, Recounts.Minute, Recounts.BurrowCount,
Recounts.NephropsIn, Recounts.NephropsOut, Recounts.StopTime,
Recounts.StartTime, UnusuableRecountMinsTable.Unusuable
HAVING (((UnusuableRecountMinsTable.Unusuable) Is Null));
        ")
Recounts_clean <- sqlFetch(channel, "Recounts-Clean")
```

3.3 Remove banana stations (outside FU20-21) and counters who failed Lin's CCC

```
# Check station numbers
length(unique(Recounts_clean$Video_Line_Name))

## [1] 96

unique(Recounts_clean$Video_Line_Name)

##  [1] 205 209 204 203 202 208 213 214 215 216 229 222 164 172 180 1
89 195
## [18] 194 230 231 232 233 239 245 218 217 210 211 212 246 240 241 2
34 224
## [35] 223 207 206 196 197 198 199 192 191 190 181 173 167 161 165 1
66 221
## [52] 220 227 228 237 238 244 249 248 247 243 242 193 186 185 184 1
83 182
## [69] 174 168 169 175 176 177 200 201 188 179 178 187 252 159 250 1
```

```
58 162
## [86] 157 171 170 163 160 251 236 235 225 226 219

# Remove Banana stations
Recounts_clean <- Recounts_clean[!Recounts_clean[, "Video_Line_Name"]
%in%
    c(250, 251, 252), ]

# remove counters from Lins check
Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    202 & Recounts_clean$VideoOperatorID == 15), ]

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    223 & Recounts_clean$VideoOperatorID == 35), ]

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    224 & Recounts_clean$VideoOperatorID == 15), ]

# Check station numbers
length(unique(Recounts_clean$Video_Line_Name))

## [1] 93

unique(Recounts_clean$Video_Line_Name)

##  [1] 205 209 204 203 202 208 213 214 215 216 229 222 164 172 180 1
89 195
## [18] 194 230 231 232 233 239 245 218 217 210 211 212 246 240 241 2
34 224
## [35] 223 207 206 196 197 198 199 192 191 190 181 173 167 161 165 1
66 221
## [52] 220 227 228 237 238 244 249 248 247 243 242 193 186 185 184 1
83 182
## [69] 174 168 169 175 176 177 200 201 188 179 178 187 159 158 162 1
57 171
## [86] 170 163 160 236 235 225 226 219
```

3.4 Switch to use the review station data

```
workplan <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SE
A/",
    "Historical review Labadie 2016/final data/2016_QC_FU2021_WorkPla
n.csv"),
    colClasses = "character")
workplan <- workplan[, c("Station", "First", "Second")]

# select the sea counts from the other 77 stations
sea_dat <- Recounts_clean[!Recounts_clean[, "Video_Line_Name"] %in% w
orkplan$Station,
    ]
length(unique(sea_dat$Video_Line_Name))

## [1] 77

# sea_dat <- sea_dat[!sea_dat[,'VideoOperatorID'] %in% c(29:34),]

# select the validation counts from the reviewed 16 stations
val_dat <- Recounts_clean[Recounts_clean[, "Video_Line_Name"] %in% wo
```

```
rkplan$Station,
    ]
validation_counters <- c(12, 15, 34, 35, 36, 37)
val_dat <- val_dat[val_dat[, "VideoOperatorID"] %in% validation_count
ers,
    ]
length(unique(val_dat$Video_Line_Name))

## [1] 16

unique(val_dat$VideoOperatorID)

## [1] 34 37 12 15 35 36

# combine sea counts and validation counts

Recounts_clean <- rbind(sea_dat, val_dat)

Recounts_AvgMin <- with(Recounts_clean, aggregate(BurrowCount, by = l
ist(Minute,
    Video_Line_Name), FUN = mean))
colnames(Recounts_AvgMin) <- c("Minute", "StationNumber", "Average")

DOG <- sqlFetch(channel, "DistanceOverGroundFinal")
close(channel)

dat <- left_join(Recounts_AvgMin, DOG, by = c("StationNumber", "Minut
e"))
dat$Area <- dat$CountedDistance * 0.75


dat1 <- dat %>% group_by(StationNumber) %>% summarise(dist = sum(Coun
tedDistance),
    area = sum(Area), burrowcount = sum(Average)) %>% mutate(density
= burrowcount/area)

nep2 <- left_join(dat1, nep1, by = c("StationNumber"))

# apply correction factor to raw densities
nep2$AdjustedBurrowDensity <- nep2$density/1.26
```

3.5 Begin krigging analysis

```
nep2 <- nep2[, c("Year", "USBL_Mid_Longitude", "USBL_Mid_Latitude", "
AdjustedBurrowDensity")]
surv.yr <- nep2$Year[1]
mt <- paste(surv.yr, "FU20-21 UWTV Density_Validation")
data.db <- db.create(nep2, flag.grid = FALSE, ndim = 2, autoname = F
)
# Data management (define lat/lon)
data.db <- db.locate(data.db, 3:4, loctype = "x")
# data.db@locators[1] <- 'rank' data.db@locators[2] <- 'Year' Data
# management (define density)
data.db <- db.locate(data.db, 5, loctype = "z")
projec.define(projection = "mean", db = data.db)

##
## Parameters for projection
## -------------------------
```

```
## Projection is switched ON
## Use 'projec.define' to modify previous values

projec.toggle(mode = 0)
```

3.5.1 Load a polygon delimiting the research survey domain and create polygon structure

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2016/Kriging")
pol.FU2021 <- read.table("pol.Labadie.IBP.csv", header = T, sep = ","
)
poly <- polygon.create(x = pol.FU2021$x, y = pol.FU2021$y)

db.poly <- polygon.create(x = pol.FU2021[, 1], y = pol.FU2021[, 2], p
olygon = NA)
europa <- read.table("europa.txt", header = T)
plot(data.db, title = mt, inches = 5, asp = 1/cos(mean(db.extract(dat
a.db,
    "x1")) * pi/180), xlim = c(-9.5, -6.65), ylim = c(49.5, 51.2))
plot(poly, col = 8, add = T)
polygon(europa, col = 8)
box()
```

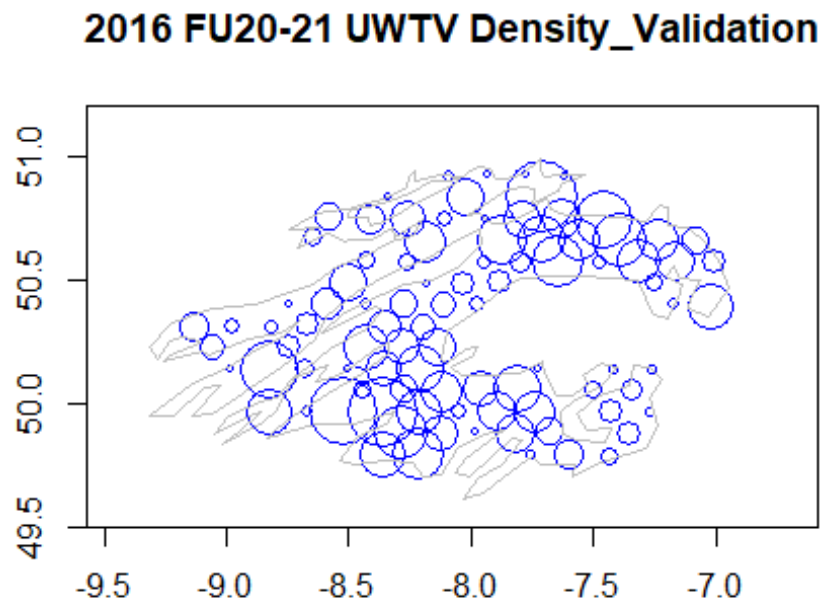


Figure 4. 2016 FU20-21 UWTV Density validation map with polygon delimiting the research survey domain.

3.6 Visualizing the dataset (in projected space based on the mean of the points)

Then checking for points inside and outside the polygon. Ensure data are same as that in 2016.

```
projec.define(projection = "mean", db = data.db)
```

```
##
## Parameters for projection
## -------------------------
## Projection is switched ON
## Use 'projec.define' to modify previous values

projec.toggle(mode = 1)

##
## Parameters for projection
## -------------------------
## Projection is switched ON
## Use 'projec.define' to modify previous values

plot(data.db, title = mt, inches = 5, asp = 1, xlim = c(-50, 50), yli
m = c(-50,
    50))
plot(poly, col = 8, add = T)
europa.p <- projec.operate(x = europa$x, y = europa$y)
polygon(europa.p, col = 8)
box()
```

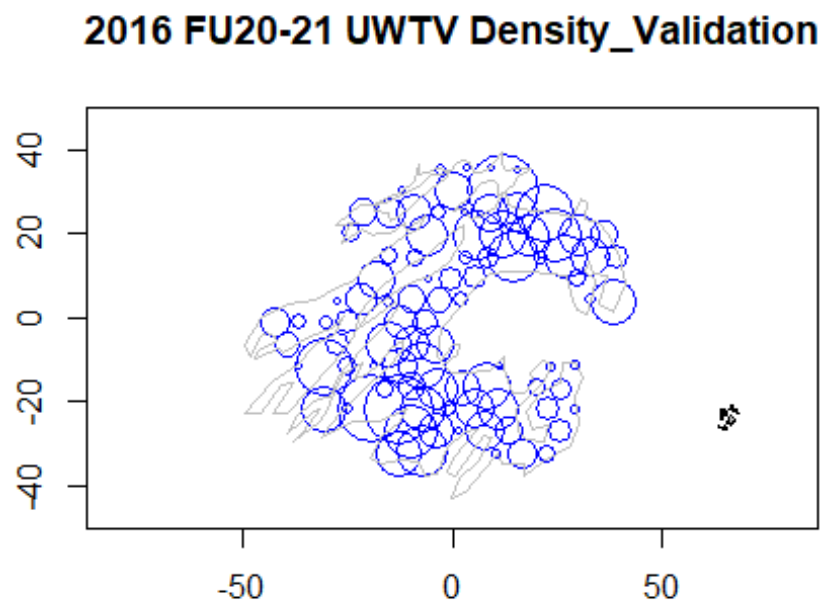


Figure 5. 2016 FU20-21 UWTV Density validation map with polygon delimiting the research survey domain. Other projection

```
db.c1 <- data.db
# select points inside polygon
db.c1 = db.polygon(db.c1, db.poly)
cat("nb points: ", db.c1$nech, " ; outside polygon: ", sum(!db.c1@ite
ms$Polygon),
    "\n")

## nb points:  93  ; outside polygon:  1
```

3.7 Getting summary statistics for inside the polygon

```
# mean, variance, histogramme of data inside polygon
zm <- mean(db.c1[, 5][db.c1[, 6]], na.rm = T)
zv <- var(db.c1[, 5][db.c1[, 6]], na.rm = T) * (sum(db.c1[, 6], na.rm
= T) -
    1)/sum(db.c1[, 6], na.rm = T)
cat("mean: ", zm, "    var: ", zv, "   cv: ", sqrt(zv)/zm, "\n")

## mean:  0.18980601     var:  0.019652999    cv:  0.73859177

hist(db.c1[, 5][db.c1[, 6]], nclass = 20, xlab = "burrow density n/m²
",
    main = mt)
```

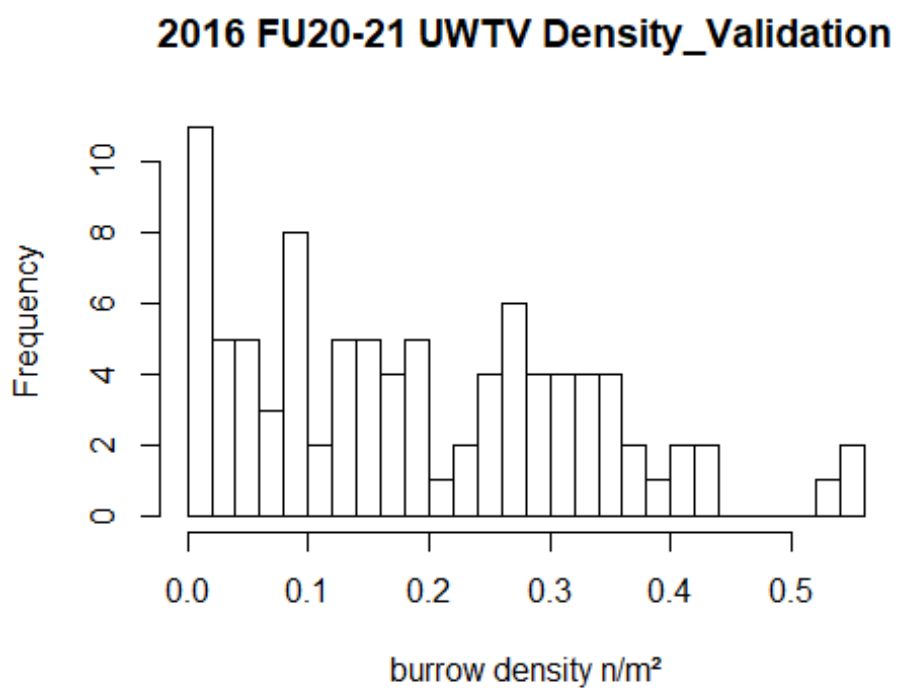


Figure 6. 2016FU20-21 UWTV Density validation barplot

3.8 Setting up the experimental variogram and plotting the points Fitting an experimental variogram to the pairs.

```
Lag = 2.2
Nlag = 19
vg1 = vario.calc(db.c1, lag = Lag, nlag = Nlag)
vario.plot(vg1, npairpt = 1, xlab = "Distance", ylab = "Variogram", p
ch = 9,
    cex = 0.001, col = "grey", title = mt)
```

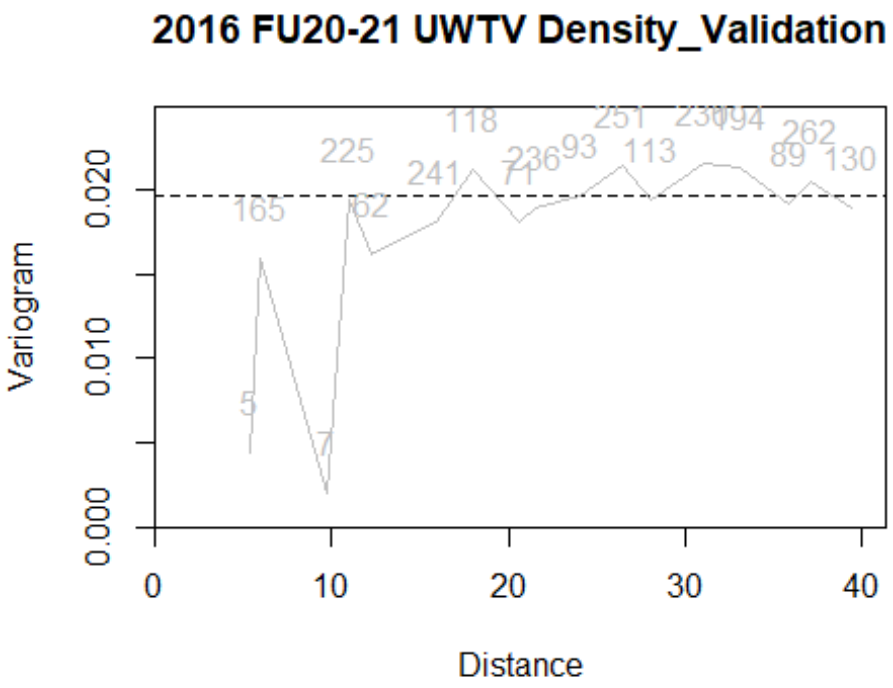


Figure 7. 2016 FU20-21 UWTV Density validation variogram

```
vg.fit = model.auto(vg1, struc = c("Spherical"), title = paste(mt, "a
uto fit Spherical"),
    xlab = "Distance", ylab = "variogram")
```

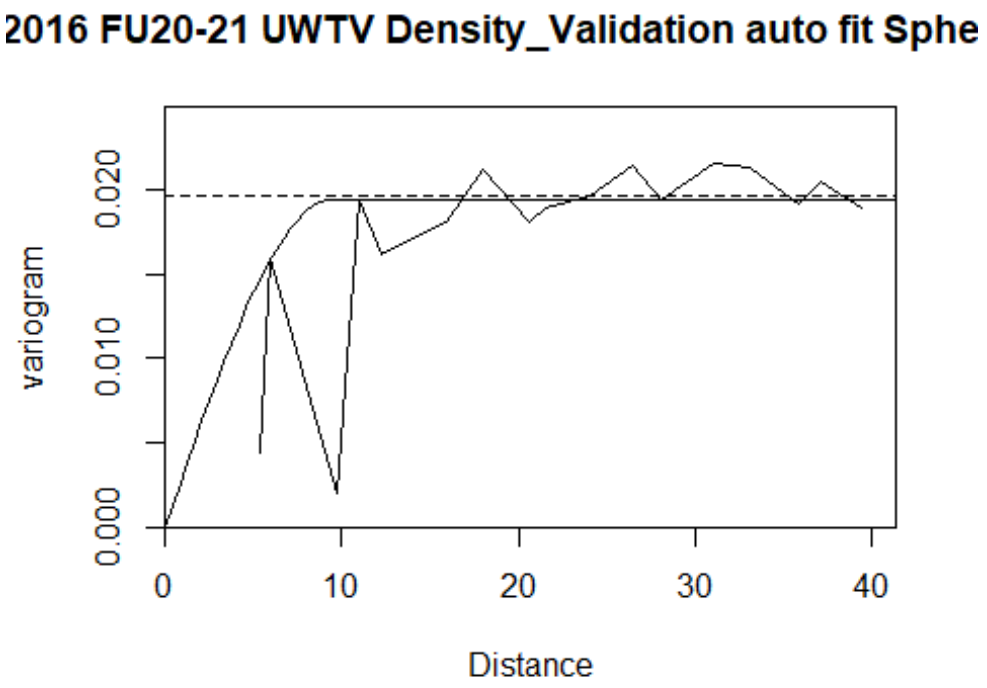


Figure 8. 2016 FU20-21 UWTV Density validation spherical variogram

```
vg.fit

##
## Model characteristics
## ======================
## Space dimension              = 2
## Number of variable(s)        = 1
## Number of basic structure(s) = 1
## Number of drift function(s)  = 1
## Number of drift equation(s)  = 1
##
## Covariance Part
## ---------------
## - Spherical
##   Range       =      9.487
##   Sill        =      0.019
## Total Sill    =      0.019
##
## Drift Part
## ----------
## Universality Condition
```

3.9 Grid the data

This step involves making a grid of points within the domain area. This grid is used for the modelled surface. A grid of 100X100 points was choosed because it was similiar to the previous methodology in SURFER. The grid is plotted along with the domain boundary and bubbles of density.

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2016/Kriging")
```

```
poldat <- read.table("pol.Labadie.IBP.csv", header = T, sep = ",")

gnx = 100
gny = 100
gx0 = min(poldat$x)
gx1 = max(poldat$x)
gy0 = min(poldat$y)
gy1 = max(poldat$y)
gdx = (gx1 - gx0)/gnx
gdy = (gy1 - gy0)/gny
gd.disc = db.create(flag.grid = T, x0 = c(gx0, gy0), dx = c(gdx, gdy)
,
    nx = c(gnx, gny))
gd.disc = db.polygon(gd.disc, db.poly)
plot(gd.disc, pch = 3, col = 1)
plot(db.c1, add = T, pch = 21)
plot(db.poly, add = T)
```

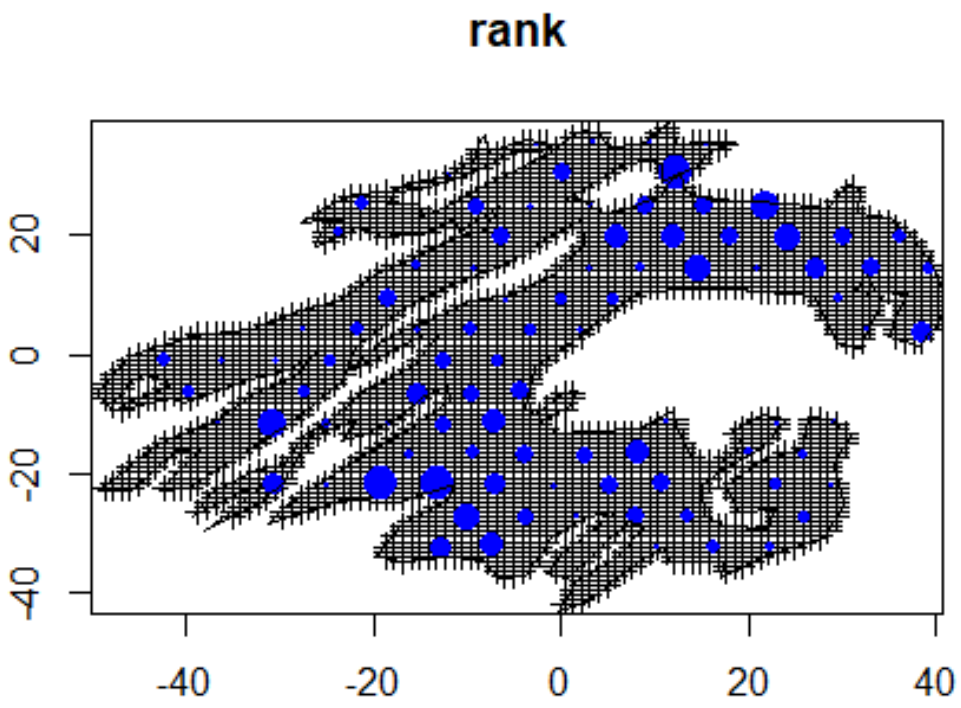


Figure 9. 2016 FU20-21 UWTV grid map with densities per station.

3.9.1 Calculate the mean burrow density and geostistical CV for the grid

This mean and CV is different from the krigging estimates calculated later but they should be fairly close for this type of dataset.

```
# calculation of CVV
cvv = model.cvv(polygon = db.poly, model = vg.fit, ndisc = c(gnx, gny
))
# Global estimate = arithmetic mean. s2est=cvv+cxx-2*cxv
cxx = model.cxx(db1 = db.c1, model = vg.fit)
```

```
cxv = model.cxv(db = db.c1, polygon = db.poly, model = vg.fit, ndisc
= c(gnx,
    gny))
sse = sqrt(cvv + cxx - 2 * cxv)
cat("arith.mean: ", round(zm, 5), " CV.geo: ", round(sse/zm, 5), "\n
")

## arith.mean:  0.18981  CV.geo:  0.04749
```

3.10 Kriging using the fitted variogram

Neighbourhood weighting is not needed given the properties of this dataset (i.e. <50 observations which are fairly homogoneous and strongly auto-corellated).

The krigged surface and the error structure is plotted for you to take a look at.

The grid is saved for plotting purposes later.

The mean z estimate from kriging is multiplied by the polygon surface 9974.43310404km^2 to calculate the total abundance.

The summary object contains all the salient infomation for the final results.

```
global.ma = global(dbin = db.c1, dbout = gd.disc, model = vg.fit, uc
= c("1"),
    polygon = db.poly, calcul = "krige", flag.polin = T, flag.wgt = F
,
    ivar = 1, verbose = 1)

## Global estimation kriging
## =========================
## Total number of data              = 93
## Number of active data             = 92
## Number of variables               = 1
## Cvv                               = 0.000271
## Estimation by kriging             = 0.197061
## Lagrange Parameter #1             = -0.000082
## Estimation St. Dev. of the mean   = 0.008618
## CVgeo                             = 0.043732
##
## Surface                           = 2908.079382
## Q (Estimation * Surface)          = 573.068813

toto <- db.create(x1 = pol.FU2021[, 1], x2 = pol.FU2021[, 2])
grid <- db.grid.init(toto, nodes = 100)  # number of nodes if related
with the fining of the grid
# when using all data as neighbours
uniquenei <- neigh.init(2, 0)

## The function 'neigh.init'will soon become obsolete
## Please use function 'neigh.create' instead (same arguments)

kri <- kriging(dbin = db.c1, db.polygon(grid, poly), vg.fit, uniquene
i)
plot(kri, col = tim.colors(200), asp = 1, xlim = c(-50, 50), ylim = c
(-50,
    50), name.image = "Kriging.AdjustedBurrowDensity.estim")
plot(poly, col = 22, add = T)
plot(db.c1, col = "black", add = T)
```

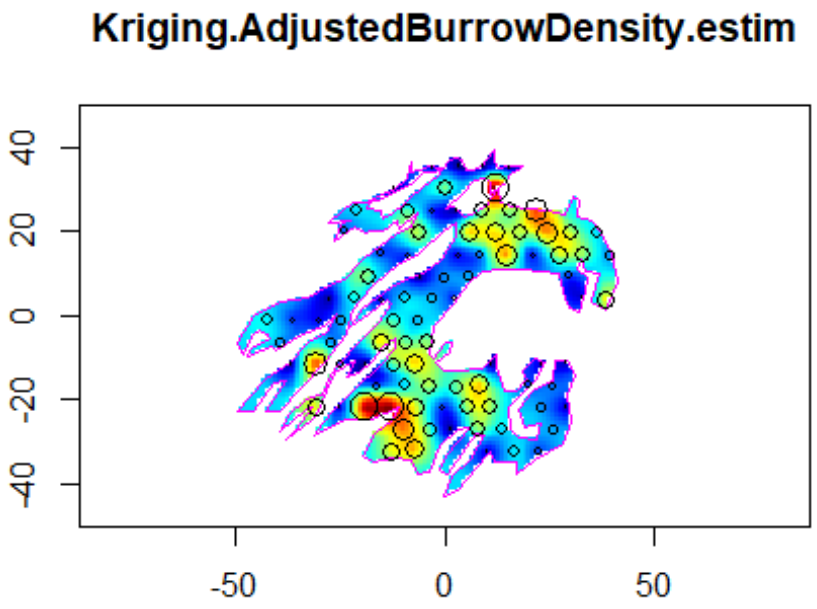


Figure 10: 2016 FU20-21 UWTV contour map for the adjusted burrow density estimates

```
plot(kri, col = tim.colors(10), asp = 1, xlim = c(-50, 50), ylim = c(
-50,
    50), name.image = "Kriging.AdjustedBurrowDensity.stdev")  #map th
e estimation variance
plot(poly, col = 22, add = T)
plot(db.c1, col = 1, add = T)
```

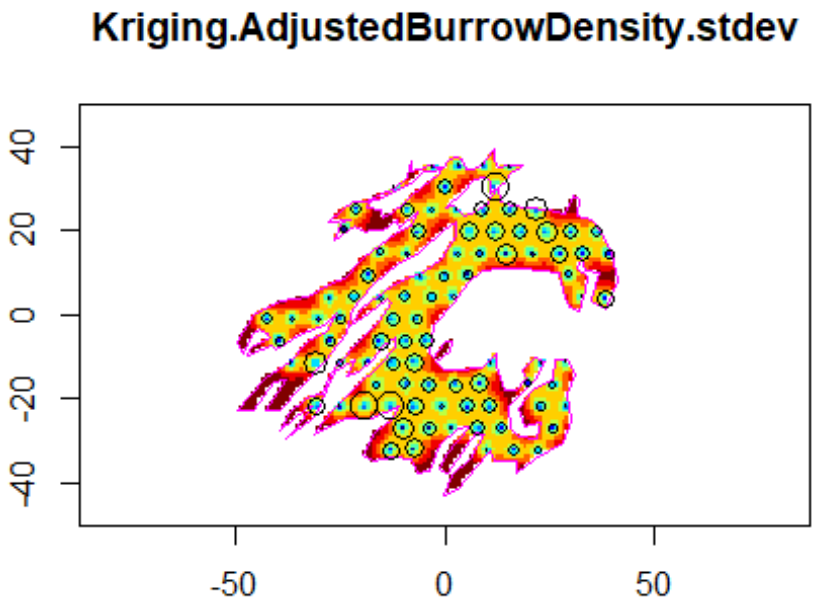


Figure 11: 2016 FU20-21 UWTV contour map for the adjusted burrow density standard deviations

```
ggin <- as.data.frame(kri@items)

write.csv(ggin, file = paste0("ggin", surv.yr, "_Historical_review.cs
v"))

# Survey abundance estimate in numbers (millions)
abun <- global.ma$zest * poly$surface * 1.852^2
```

3.11 Results

```
# read in summary file from surfer calculation
k.sum <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/2
018 Labadie/",
    "Kriging/Labadie_Summary_ADG_2018.csv"))

k.sum <- k.sum[-1]
k.sum <- subset(k.sum, Year < 2017)

k.sum <- rbind(k.sum, data.frame(Year = nep2$Year[1], Ground = "FU202
1",
    mean = zm, N = db.c1$nech, sd = zv/zv^0.05, se = sse, ciMult = N
A,
    ci = abun * global.ma$cv * 1.96, area = poly$surface * 1.852^2, a
bund = abun,
    upper = abun + abun * global.ma$cv * 1.96, lower = abun - abun *
global.ma$cv *
        1.96, CViid = zv/zm, meanGeo = global.ma$zest, CVgeo = global
.ma$cv))

k.sum$method <- c(rep("ORIGINAL COUNTS", 4), "HISTORICAL REVIEW")

k.sum2016 <- k.sum[4:5, ]


knitr::kable(k.sum2016[, c(1:2, 16, 3:6)], caption = paste0("2016 FU2
0-21 UWTV",
    " Summary results of the kriging from the Original survey counts
and",
    " from the Validation review counts. Density and abundance estima
tes"))
```

Table 5. 2016 FU20-21 UWTV Summary results of the kriging from the Original survey counts and from the Validation review counts. Density and abundance estimates

	Year	Ground	method	mean	N	sd	se
4	2016	FU2021	ORIGINAL COUNTS	0.18000000	93	0.02000000	0.01000000
5	2016	FU2021	HISTORICAL REVIEW	0.18980601	93	0.02391979	0.00901453

```
knitr::kable(k.sum2016[, c(1:2, 16, 8:12)])
```

	Year	Ground	method	ci	area	abund	upper	lower
4	2016	FU2021	ORIGINAL COUNTS	147.00000	9974.0000	1879.000	2026.3136	1731.6864
5	2016	FU2021	HISTORICAL REVIEW	168.47792	9974.4331	1965.571	2134.0489	1797.0931

```
knitr::kable(k.sum2016[, c(1:2, 16, 13:15)])
```

	Year	Ground	method	CViid	meanGeo	CVgeo

4	2016	FU2021	ORIGINAL COUNTS	0.11000000	0.19000000	0.04000000
5	2016	FU2021	HISTORICAL REVIEW	0.10354256	0.19706092	0.04373188

```
write.csv(k.sum, "Labadie_Summary_ADG_2016_Historical_review.csv")
```

3.12 Final check: cross validation plot

```
data.db <- xvalid(db.c1, model = vg.fit, uniquenei)
hist(db.extract(data.db, "Xvalid.AdjustedBurrowDensity.esterr"), ncla
ss = 30,
    main = "CrossValidation", xlab = "Cross validation error", col =
"blue")
```

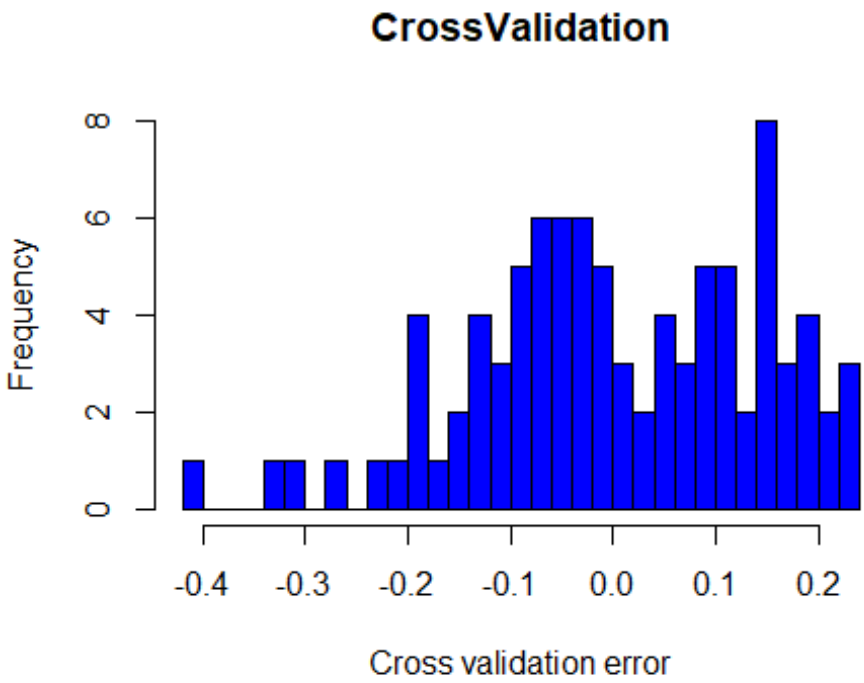


Figure 12: 2016 FU20-21 UWTV cross validation plot.

4 2017: COUNTS COMPARISON

4.1 Sample random stations

We are going to select the stations that we will review from 2017 FU20-21 footage.

- We will take only stations with more than 15 burrows for the entire TV station.
- From these stations greater than 15, we will take the stations with highest counts (two station outliers).
- From the rest of the stations > 15 burrows, we will take a random sample of 20% stations (14 stations).

In total, we will review 16 stations from 2017 FU20-21 footage.

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/2018 Labadie/Histori
cal_Review")

## Read the data and subset the year of interest
dat <- fread("fu2021_tv_final_2017.csv", select = c("FU", "Survey", "
Year",
```

```
    "Station", "Count", "MidDeglong", "MidDegLat", "Ground"))
d <- subset(dat, Year == 2017)

## Identify the outliers in each of the Years
d2017 <- subset(dat, Year == 2017)
out2017 <- boxplot(d2017$Count ~ d2017$Year, plot = F)$out
d2017[d2017$Count %in% out2017]

##      FU  Survey Year Station Count MidDeglong MidDegLat  Ground
## 1: 2021 CV17018 2017     189 248.5  -8.172635 50.670217 Labadie
## 2: 2021 CV17018 2017     178 197.5  -8.405708 50.583339 Labadie

### Steps: Remove Stations with Count < 15; Remove Outliers Stations;
### Sample a % from the rest of the Stations; Add the Outlier Station
s

### Remove Stations with Count < 15
more15 <- subset(d, Count >= 15)

### Calculate Stations in each Year with Count >= 15
more15.year <- group_by(more15, Year)
TotStat2017 <- sum(more15.year$Year == 2017)
TotStat2017

## [1] 74

### Remove Outliers Stations
more15out <- more15[more15$Year == 2017 & !more15$Count %in% out2017,
]

### SAMPLE p percentages ----
p <- seq(0.1, 0.3, by = 0.05)  # set the % you want to check

samp <- list()  # setting container for the loop
review <- list()  # setting container for the loop
SamStat2017 <- list()  # setting container for the loop

for (i in 1:length(p)) {
    ### sample p% from each Year and storage in samp
    samp[[i]] <- as.data.frame(more15out %>% group_by(Year) %>% sampl
e_frac(p[i]))

    ### add the Ourlier Stations
    review[[i]] <- rbind(samp[[i]], more15[more15$Year == 2017 & more
15$Count %in%
        out2017, ])
    ### ordering the data.frames by Year and Station numbers
    review[[i]] <- review[[i]][order(review[[i]]$Year, review[[i]]$St
ation)]

    #### How many Stations we would review with this method for each
p%?
    SamStat2017[[i]] <- sum(review[[i]]$Year == 2017)

    #### Rename the dataframes inside the containers with the their p
% values
    names(samp)[i] <- paste0("sample ", p[i] * 100, "% + outliers")
    names(review)[i] <- paste0("sample ", p[i] * 100, "% + outliers")
    names(SamStat2017)[i] <- paste0("sample ", p[i] * 100, "% + outli
ers")
```

```
}

### How many Stations to review with this method, under each p% value
?
knitr::kable(data.frame(n_2017 = unlist(SamStat2017)), caption = past
e0("Number of",
    " stations needed to be reviewed under each of the percentage opt
ions"))
```

Table 8. Number of stations needed to be reviewed under each of the percentage options

	n_2017
sample 10% + outliers	9
sample 15% + outliers	13
sample 20% + outliers	16
sample 25% + outliers	20
sample 30% + outliers	24

4.1.1 We chose to sample 20% + outliers

```
### Which Stations do we have to review with this method?
Station.rev <- lapply(review, select, c(Year,Station))
knitr::kable(Station.rev$"sample 20% + outliers", # insert the desire
d p%
             caption = '2017 FU20-21 UWTV Review stations ID')
```

Table 9. 2017 FU20-21 UWTV Review stations ID

Year	Station
2017	126
2017	138
2017	148
2017	150
2017	156
2017	158
2017	160
2017	165
2017	168
2017	178
2017	181
2017	186
2017	189
2017	193
2017	197
2017	203

4.2 Map showing the 2017 stations and the 20% historical review stations

```
# read shapefile as a SpatialPolygonsDataframe
FG <- readShapePoly("//Galwayfs03/Nephrops/Surveys/ArcGis/ShapefilesR
/NephropsGrounds_All",
    proj4string = CRS("+proj=longlat +datum=WGS84"))
EU <- readShapePoly("//Galwayfs03/Nephrops/Surveys/ArcGis/ShapefilesR
/Europe",
    proj4string = CRS("+proj=longlat +datum=WGS84"))

m <- ggplot() + geom_polygon(data = EU, aes(x = long, y = lat, group
= group),
    fill = "#006837") + geom_polygon(data = FG, aes(x = long, y = lat
,
    group = group), fill = "Light Grey")

latlimits <- c(49.6, 51.2)
longlimits <- c(-7, -9.2)

dat2 <- d %>% rename(lon = MidDeglong) %>% rename(lat = MidDegLat)
dat2 <- data.frame(dat2)
dat3 <- subset(dat2, Station %in% real.stn)

m + geom_point(data = dat3, aes(x = lon, y = lat), shape = 1, size =
8,
    colour = "red") + geom_text(data = dat2, aes(x = lon, y = lat, la
bel = (Station)),
    size = 4) + theme_bw() + coord_cartesian(xlim = longlimits, ylim
= latlimits) +
    labs(y = "Latitude", x = "Longitude")
```

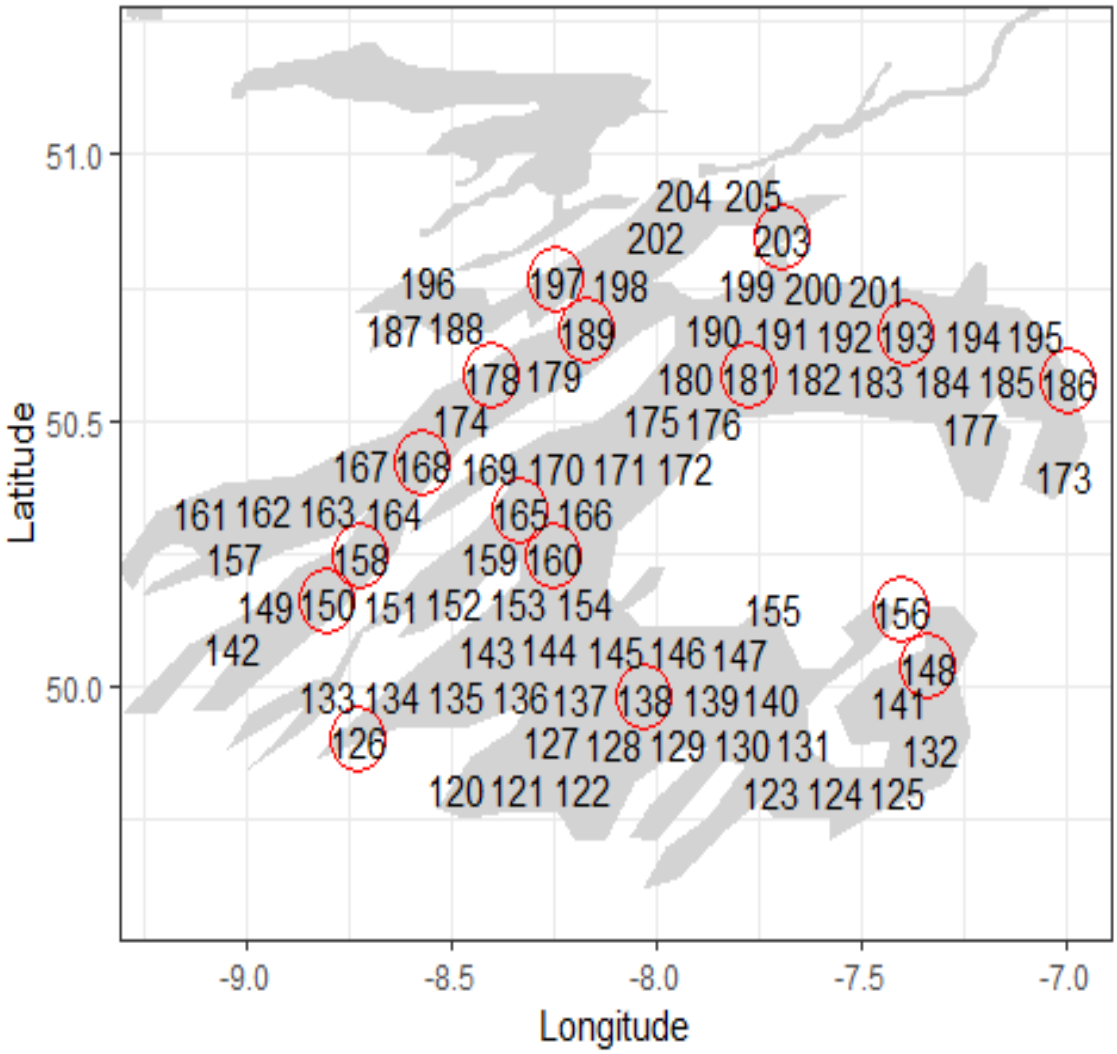


Figure 13: Map showing 2017 stations and historical review stations denoted by red circle

4.3 Read in the validation data

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2017/Final Data/")
# ensure delete additional minutes in local survey database run queri
es
# 1-5 to generate Recounts-Clean or pop them in here to code

channel <- odbcConnectAccess(paste0("N:/Surveys/UWTV SURVEYS FU2022 C
ELTIC SEA/",
    "Historical review Labadie 2017/Final Data/NEPHROPS_MULTILOG_CV17
018_Labadie"))

dataframe <- sqlFetch(channel, "Recounts")

recounts.clean <- dataframe[-which(dataframe$StartTime - dataframe$St
opTime >
    30), ]

stns <- read.csv("id_of_stations_to_review_dvd.csv")
```

```
stns <- stns[1:32, c("Year", "Station", "Count", "Count2")]
stns17 <- subset(stns, Year == 2017)

# we select the validation reviewers
rec <- recounts.clean[which(recounts.clean$Video_Line_Name %in% uniqu
e(stns17$Station)),
    ]
Recounts <- subset(rec, VideoOperatorID %in% c(12, 15, 31, 32, 33, 34
))

Ops <- sqlFetch(channel, "Video_Operator")
close(channel)
```

4.4 Check number of recount stations

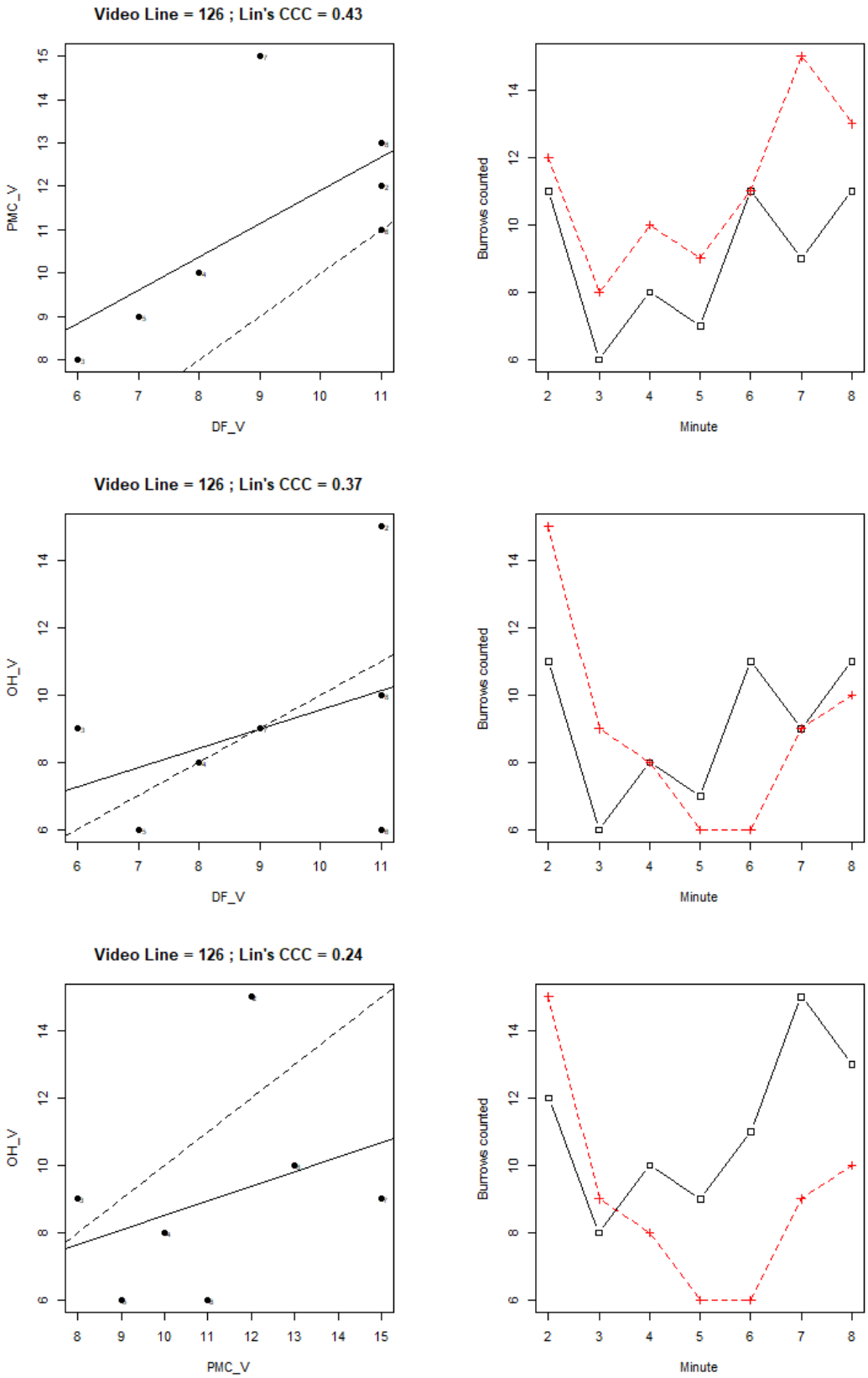
```
length(unique(Recounts$Video_Line_Name))

## [1] 16

Recounts <- Recounts[order(Recounts$Video_Line_Name, Recounts$SurveyI
D,
                           Recounts$VideoOperatorID, Recounts$Minute)
, ]

selst <- Recounts %>% group_by(Video_Line_Name) %>%
  summarise(hatn = sum(BurrowCount)/length(BurrowCount)) %>% filter(h
atn > 1.5)

selst <- as.list(selst[1])

SummedBurrow<-aggregate(BurrowCount~Video_Line_Name, sum, data = Reco
unts)
ZeroBurrow<-subset(SummedBurrow, BurrowCount > 0)
RecountsP<-subset(Recounts, Video_Line_Name %in% selst$Video_Line_Nam
e)
length(unique(Recounts$Video_Line_Name))

## [1] 16
```

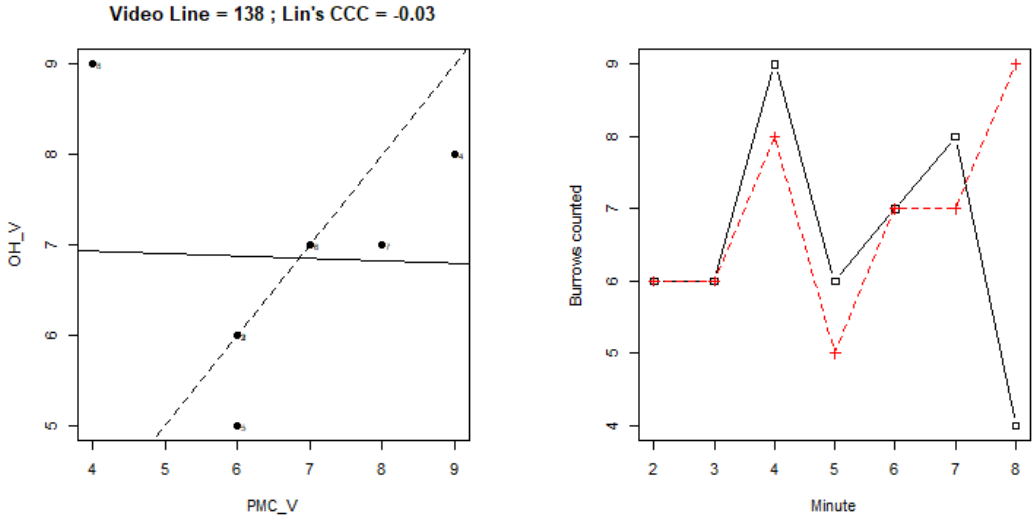
4.5 Quality control using Lin's CCC test

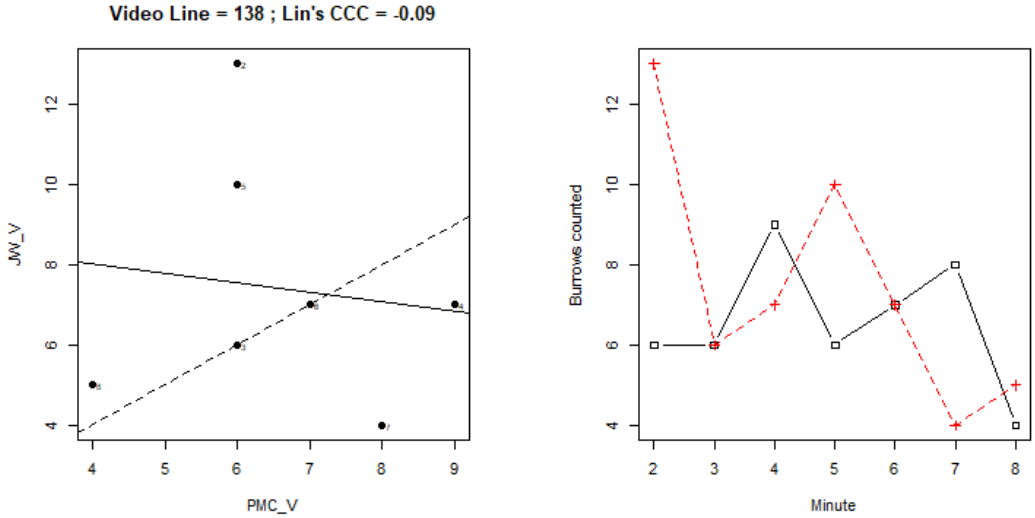
As standard on UWTV surveys run the counts to check counter performance using a threshold of 0.5 for FU20-21.

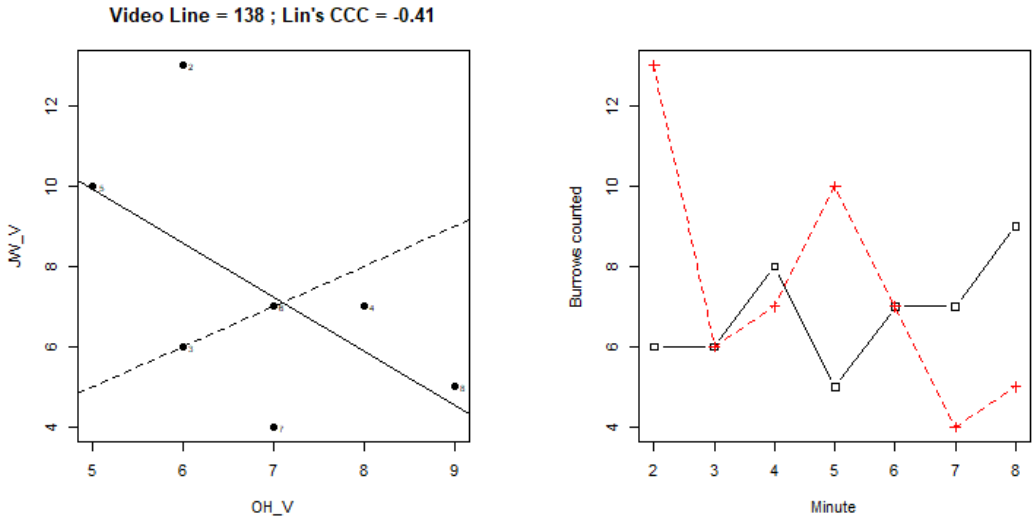
```
Lins <- 0.5
Oid <- sort(unique(RecountsP$Video_Line_Name))
par(mfrow = c(3, 2))
for (o in c(1:length(Oid))) {
    temp <- RecountsP[RecountsP$Video_Line_Name == Oid[o], ]
    temp <- temp[order(temp$Minute), ]

    Rs <- unique(temp$VideoOperatorID)
    l <- length(Rs)
    if (l > 1) {
        for (i in c(1:(l - 1))) {
            for (j in c((i + 1):l)) {
                temp2 <- temp[temp$VideoOperatorID %in% c(Rs[i], Rs[j
]),
                  ]
```

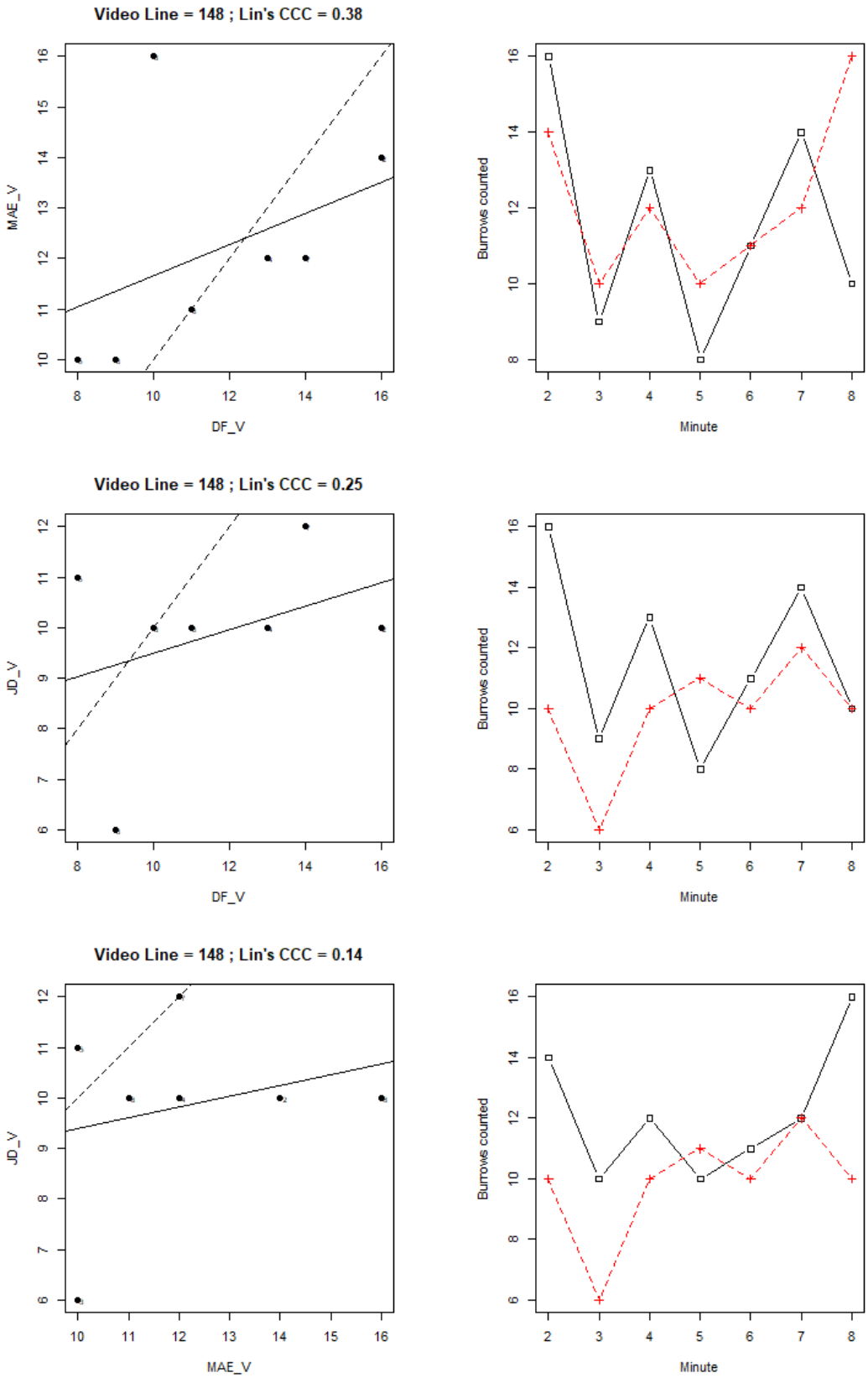
```
                temp2 <- dcast(temp2, Minute ~ VideoOperatorID, value
.var = "BurrowCount",
                  sum)
                c1 <- as.numeric(names(temp2[2]))
                c2 <- as.numeric(names(temp2[3]))
                c1 <- Ops$Initials[match(c1, Ops$VideoOperatorID)]
                c2 <- Ops$Initials[match(c2, Ops$VideoOperatorID)]

                tmp.ccc <- epi.ccc(temp2[, 2], temp2[, 3], ci = "z-tr
ansform",
                  conf.level = 0.95)
                z <- lm(temp2[, 3] ~ temp2[, 2])
                par(pty = "s")
                plot(temp2[, 2], temp2[, 3], xlab = c1, ylab = c2, pc
h = 16,
                  main = paste("Video Line =", unique(temp$Video_Line
_Name),
                    "; Lin's CCC =", round(tmp.ccc$rho.c[1], 2), sep
= " "))
                abline(a = 0, b = 1, lty = 2)
                abline(z, lty = 1)
                text(temp2[, 2] + 0.1, (temp2[, 3]), temp2[, 1], cex
= 0.6)

                plot(temp2$Minute, temp2[, 2], type = "b", col = 1, p
ch = 0,
                  lty = 1, xlab = "Minute", ylab = "Burrows counted",
xlim = range(temp2$Minute),
                  ylim = range(temp2[, 2:3]))
                points(temp2$Minute, temp2[, 3], col = 2, pch = 3)
                lines(temp2$Minute, temp2[, 3], col = 2, lty = 2)

                LinsVL <- as.data.frame(c(unique(temp$Video_Line_Name
),
                  Rs[i], Rs[j], round(tmp.ccc$rho.c[1], 2)))
                names(LinsVL) <- c("VideoLine", "Counter1", "Counter2
",
                  "LinsCCC")
                Lins <- as.data.frame(rbind(LinsVL, Lins))
            }
        }
    }
}
```

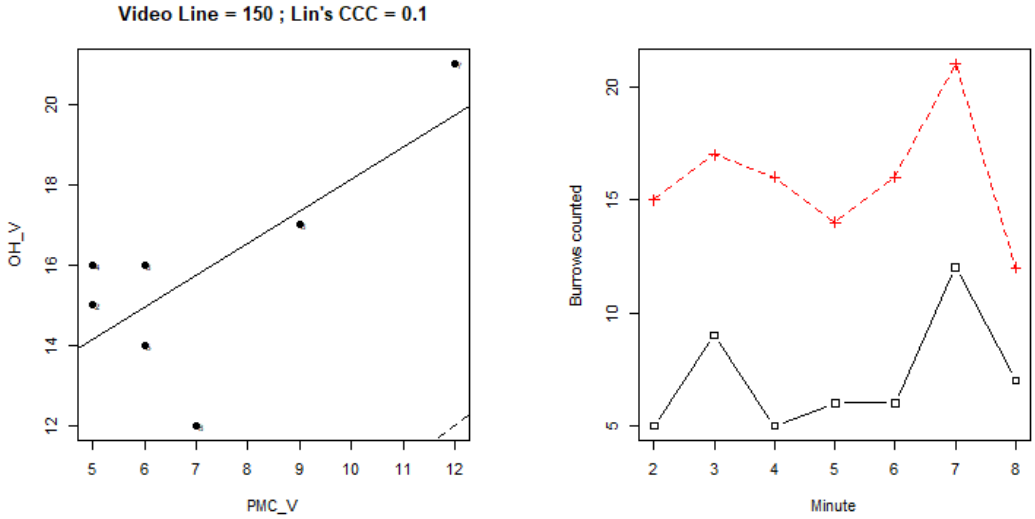

Video Line = 126 ; Lin's CCC = 0.43
PMC_V
DF_V
Burrows counted
Minute
Video Line = 126 ; Lin's CCC = 0.37
OH_V
DF_V
Burrows counted
Minute
Video Line = 126 ; Lin's CCC = 0.24
OH_V
PMC_V
Burrows counted
Minute

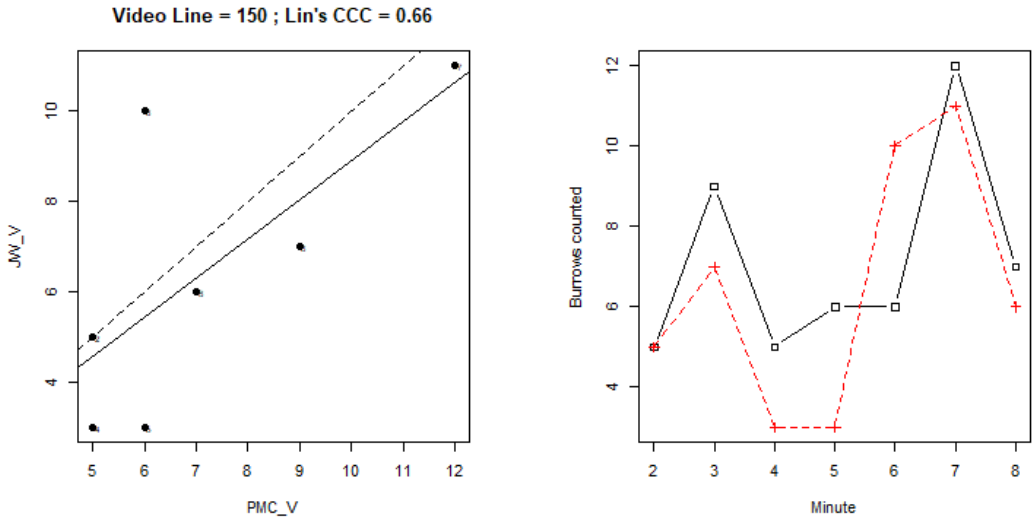

Video Line = 138 ; Lin's CCC = -0.03
OH_V
PMC_V
Burrows counted
Minute

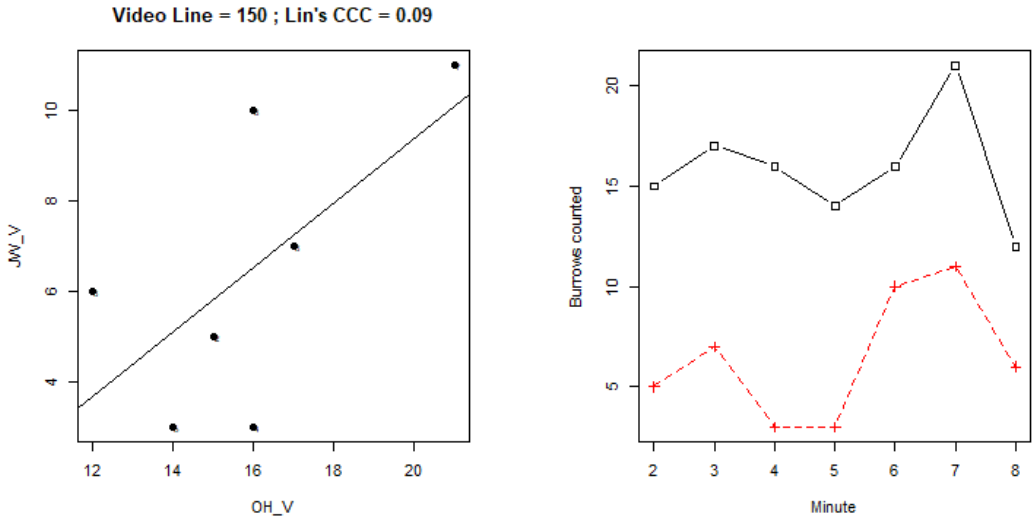

Video Line = 138 ; Lin's CCC = -0.09
JW_V
PMC_V
Burrows counted
Minute

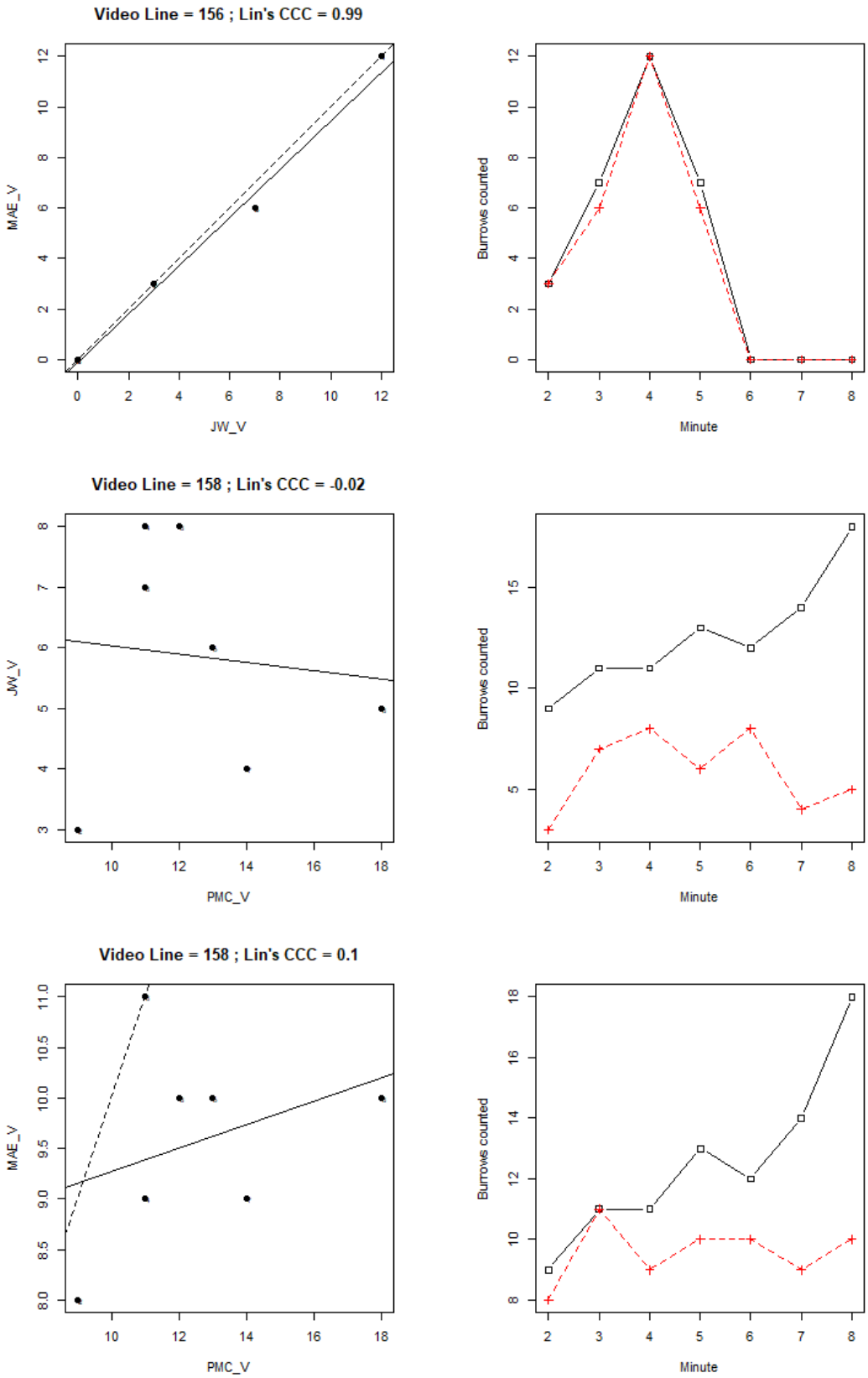

Video Line = 138 ; Lin's CCC = -0.41
JW_V
OH_V
Burrows counted
Minute

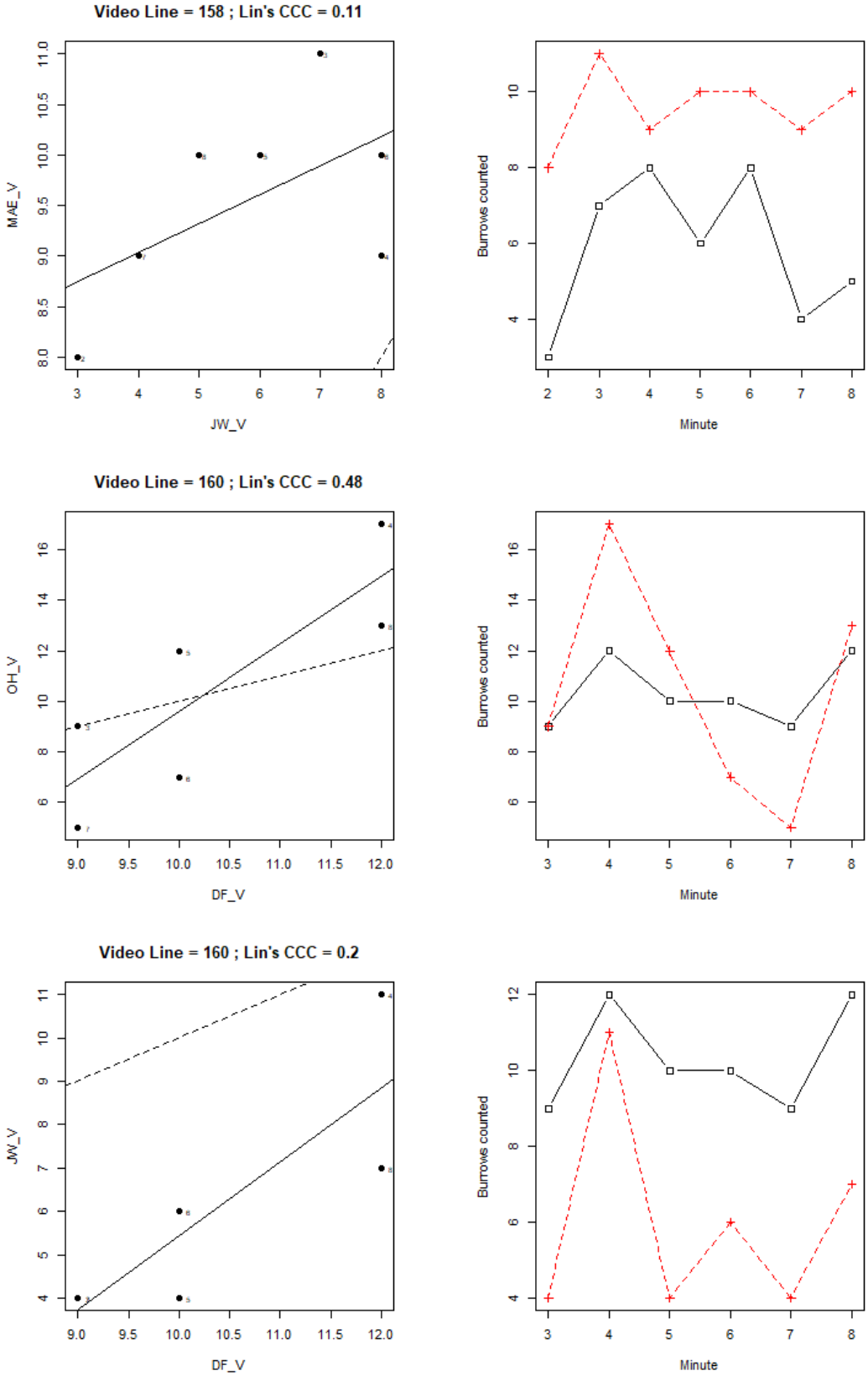

Video Line = 148 ; Lin's CCC = 0.38
MAE_V
DF_V
Burrows counted
Minute
Video Line = 148 ; Lin's CCC = 0.25
JD_V
DF_V
Burrows counted
Minute
Video Line = 148 ; Lin's CCC = 0.14
JD_V
MAE_V
Burrows counted
Minute


Video Line = 150 ; Lin's CCC = 0.1
OH_V
PMC_V
Burrows counted
Minute

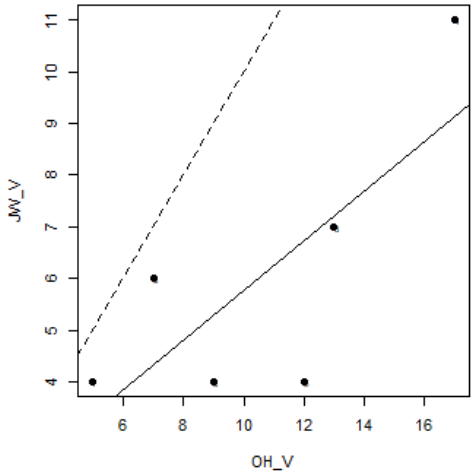

Video Line = 150 ; Lin's CCC = 0.66
JW_V
PMC_V
Burrows counted
Minute

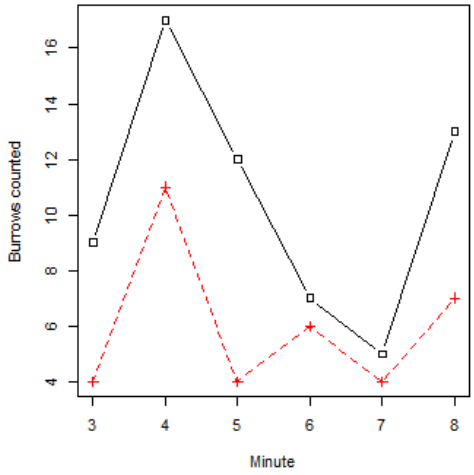

Video Line = 150 ; Lin's CCC = 0.09
JW_V
OH_V
Burrows counted
Minute


Video Line = 156 ; Lin's CCC = 0.99
MAE_V
JW_V
Burrows counted
Minute
Video Line = 158 ; Lin's CCC = -0.02
JW_V
PMC_V
Burrows counted
Minute
Video Line = 158 ; Lin's CCC = 0.1
MAE_V
PMC_V
Burrows counted
Minute

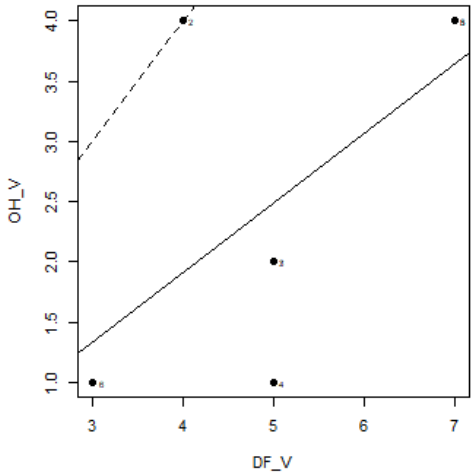

Video Line = 158 ; Lin's CCC = 0.11
MAE_V
JW_V
Burrows counted
Minute
Video Line = 160 ; Lin's CCC = 0.48
OH_V
DF_V
Burrows counted
Minute
Video Line = 160 ; Lin's CCC = 0.2
JW_V
DF_V
Burrows counted
Minute

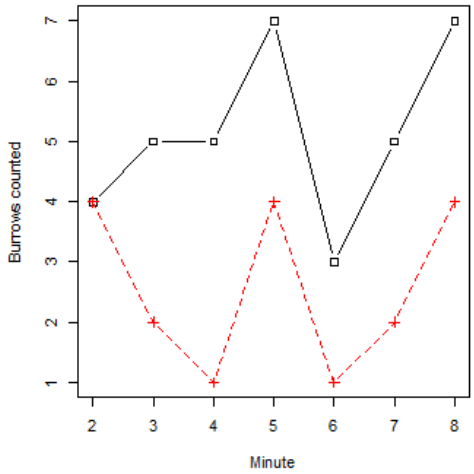
Video Line = 160 ; Lin's CCC = 0.36



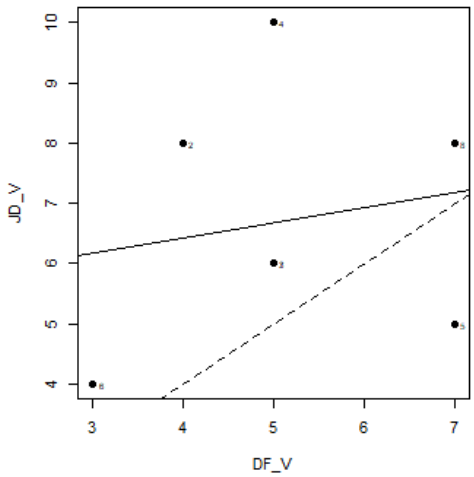


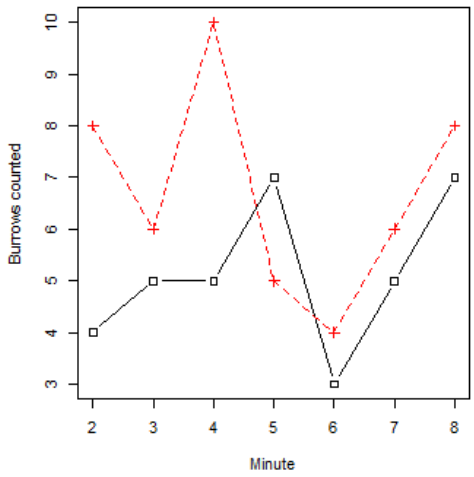
Video Line = 165 ; Lin's CCC = 0.21

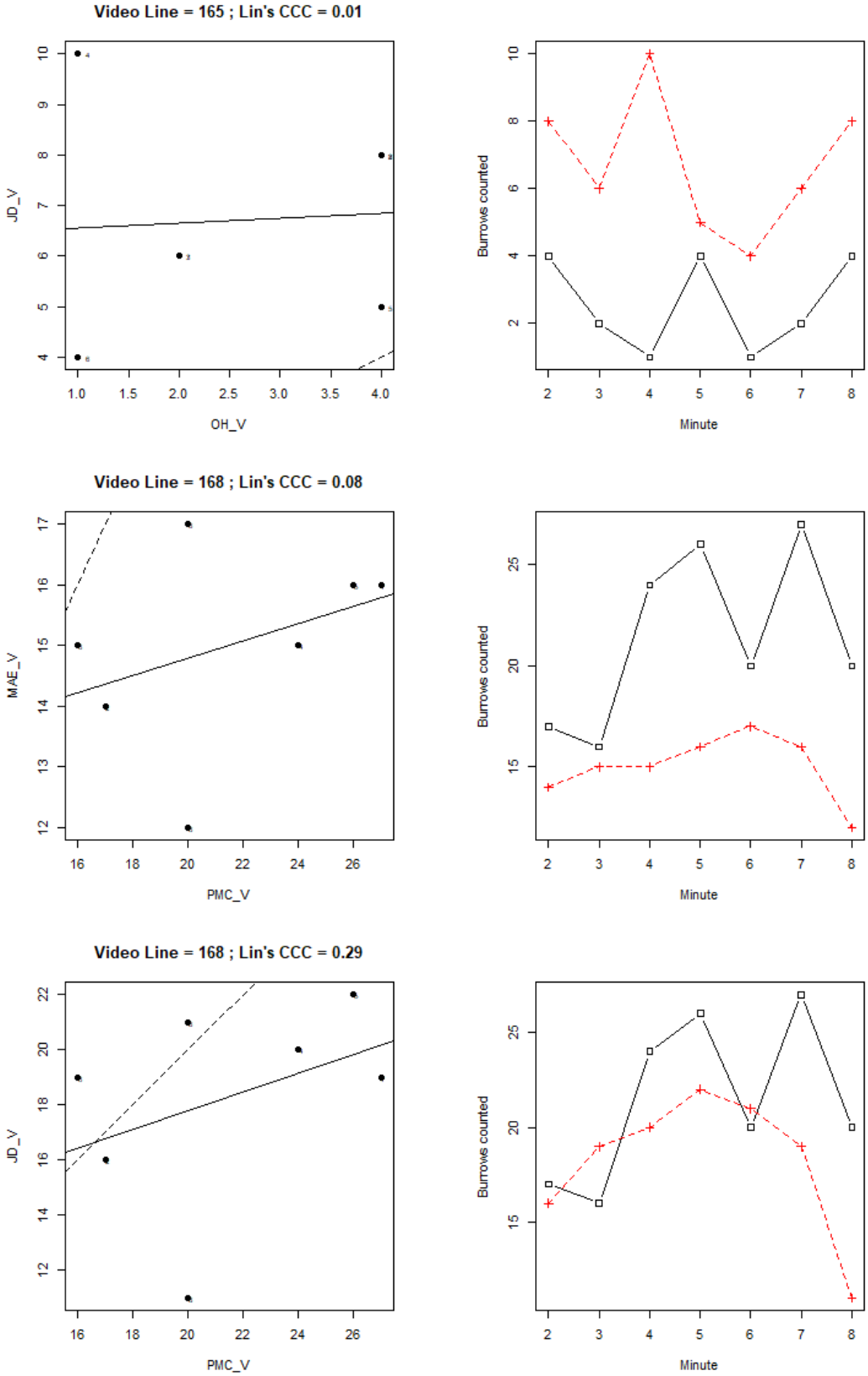


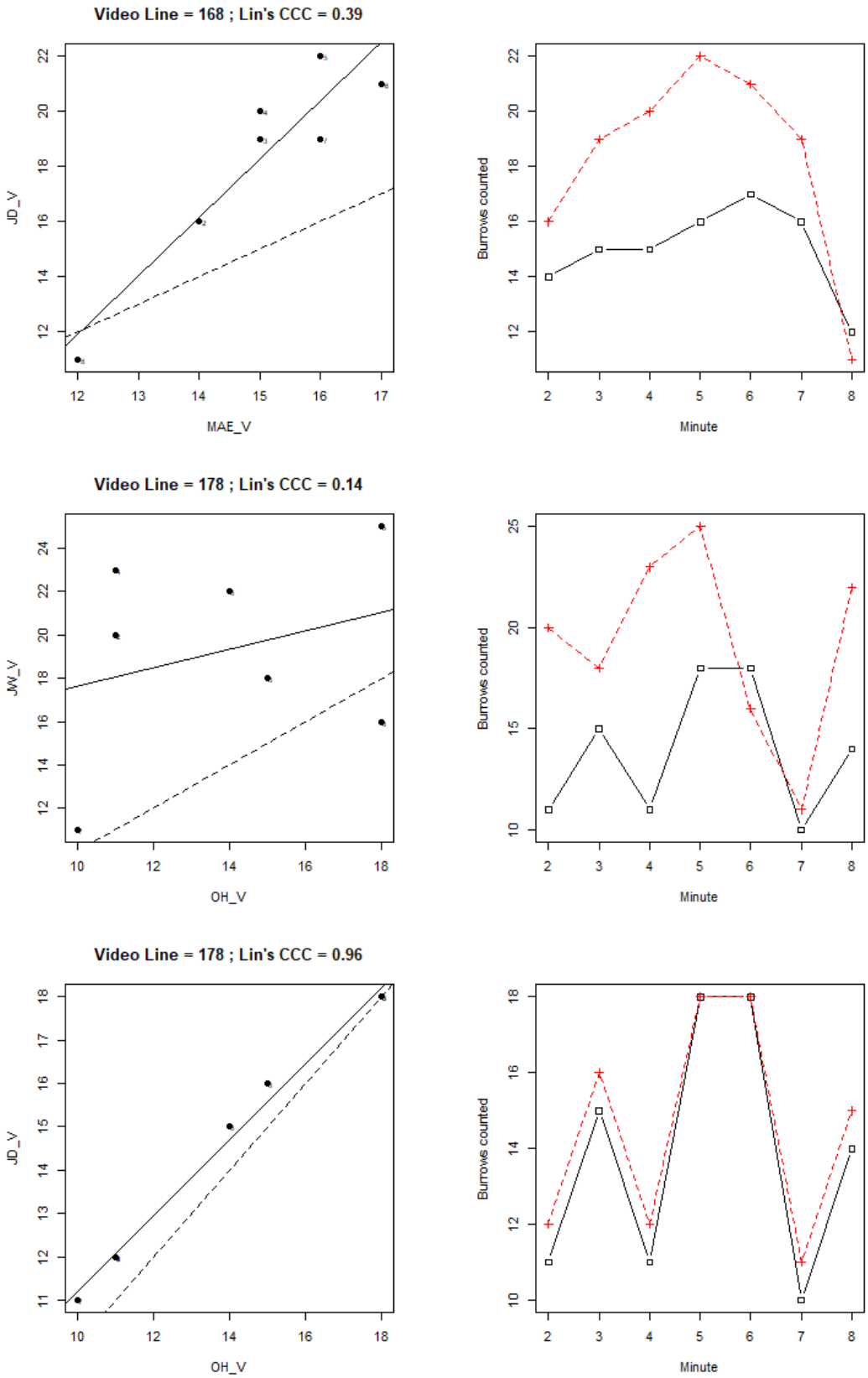


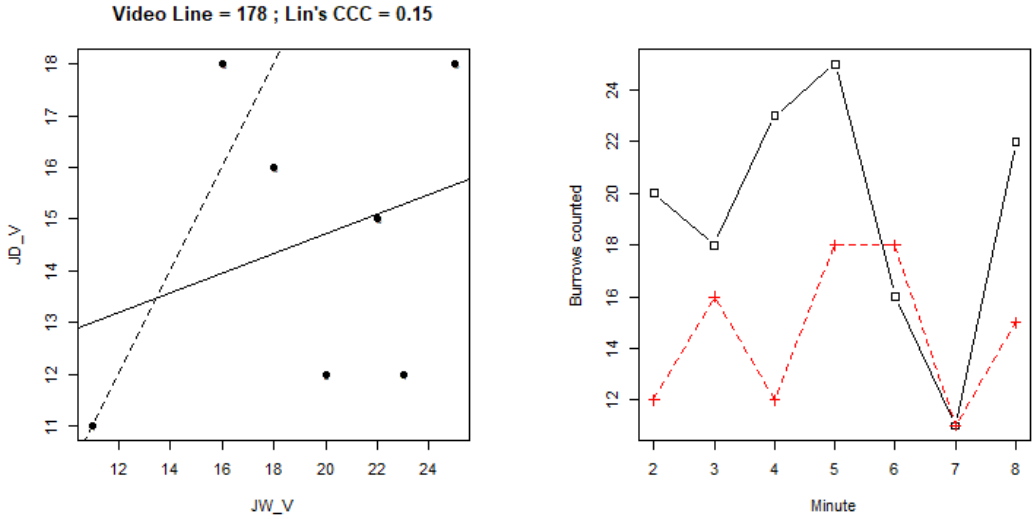
Video Line = 165 ; Lin's CCC = 0.12

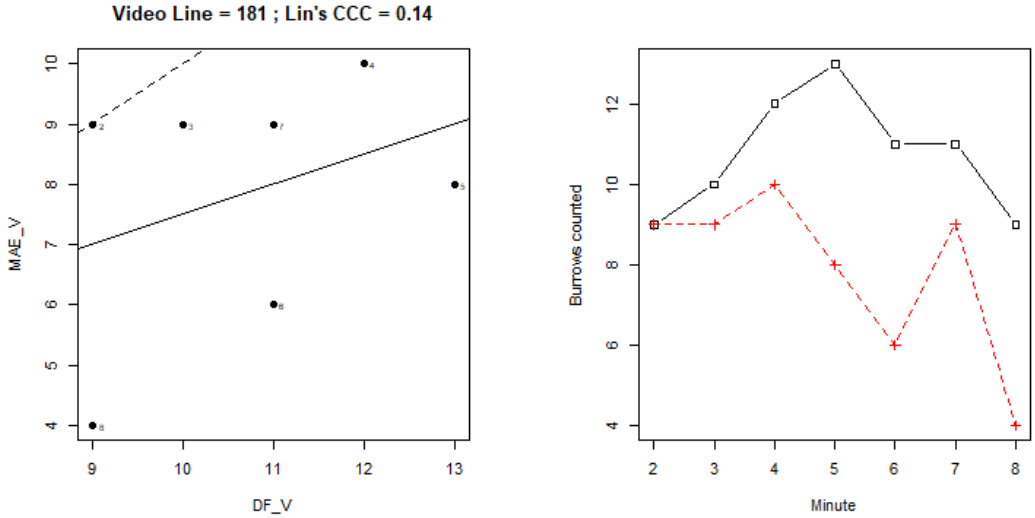


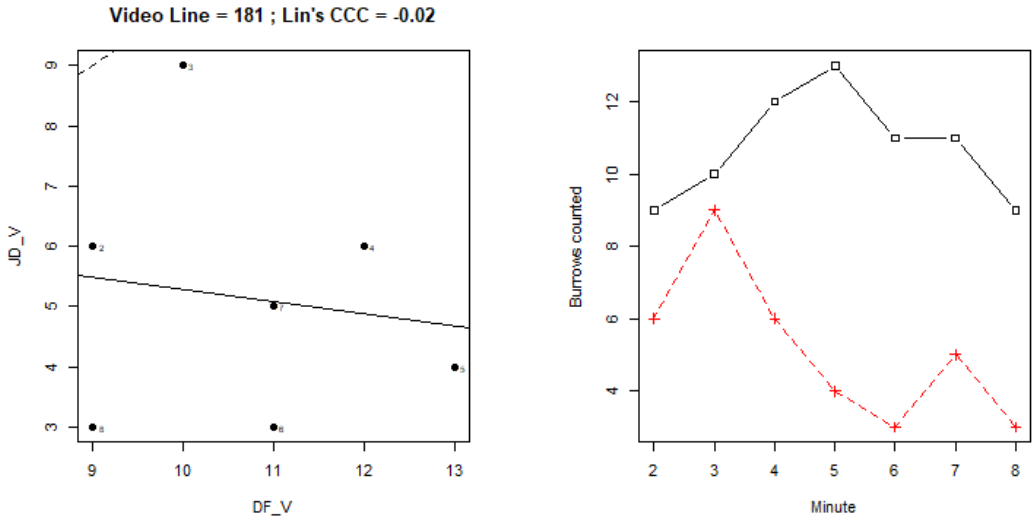


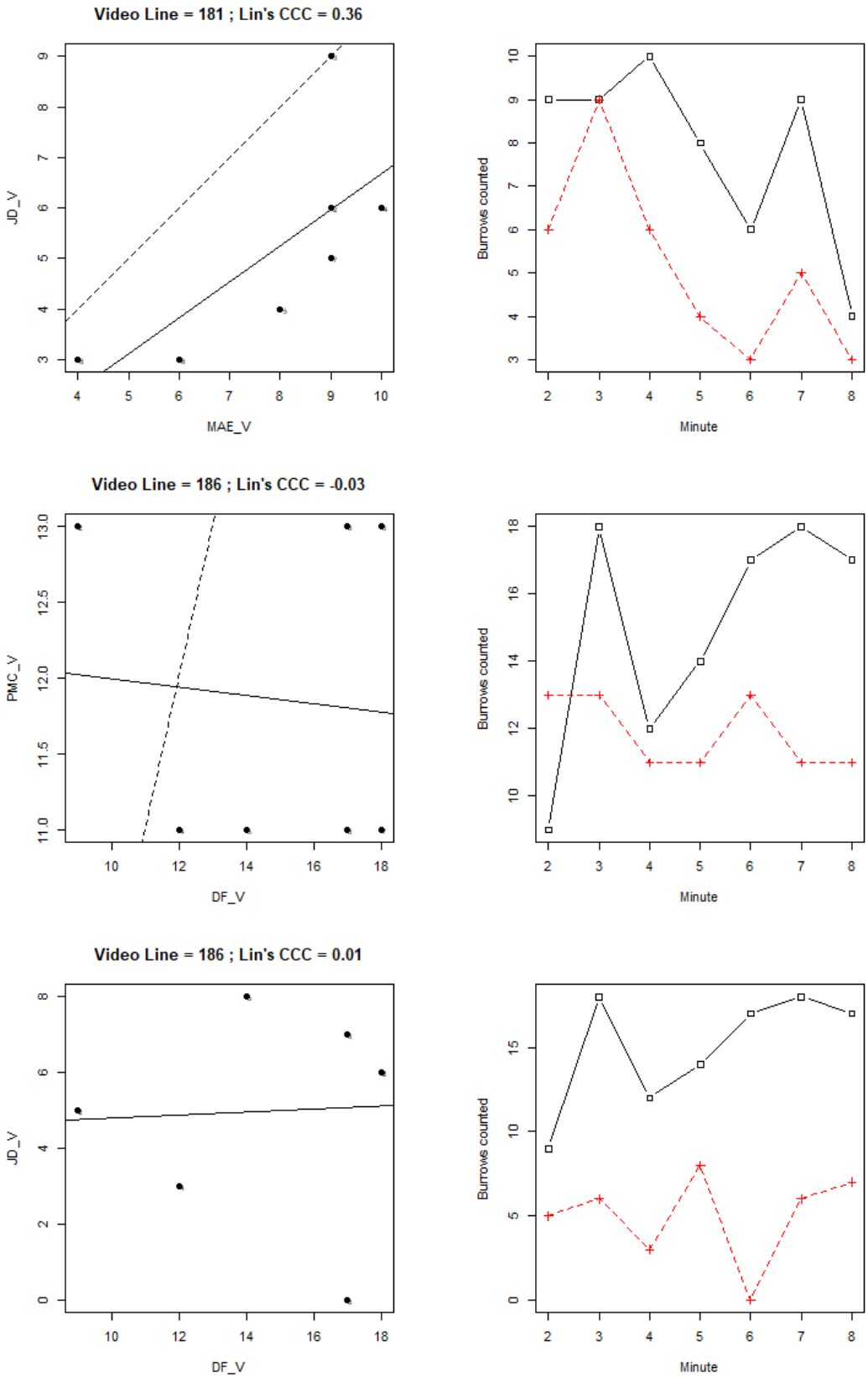

Video Line = 165 ; Lin's CCC = 0.01
JD_V
OH_V
Burrows counted
Minute
Video Line = 168 ; Lin's CCC = 0.08
MAE_V
PMC_V
Burrows counted
Minute
Video Line = 168 ; Lin's CCC = 0.29
JD_V
PMC_V
Burrows counted
Minute

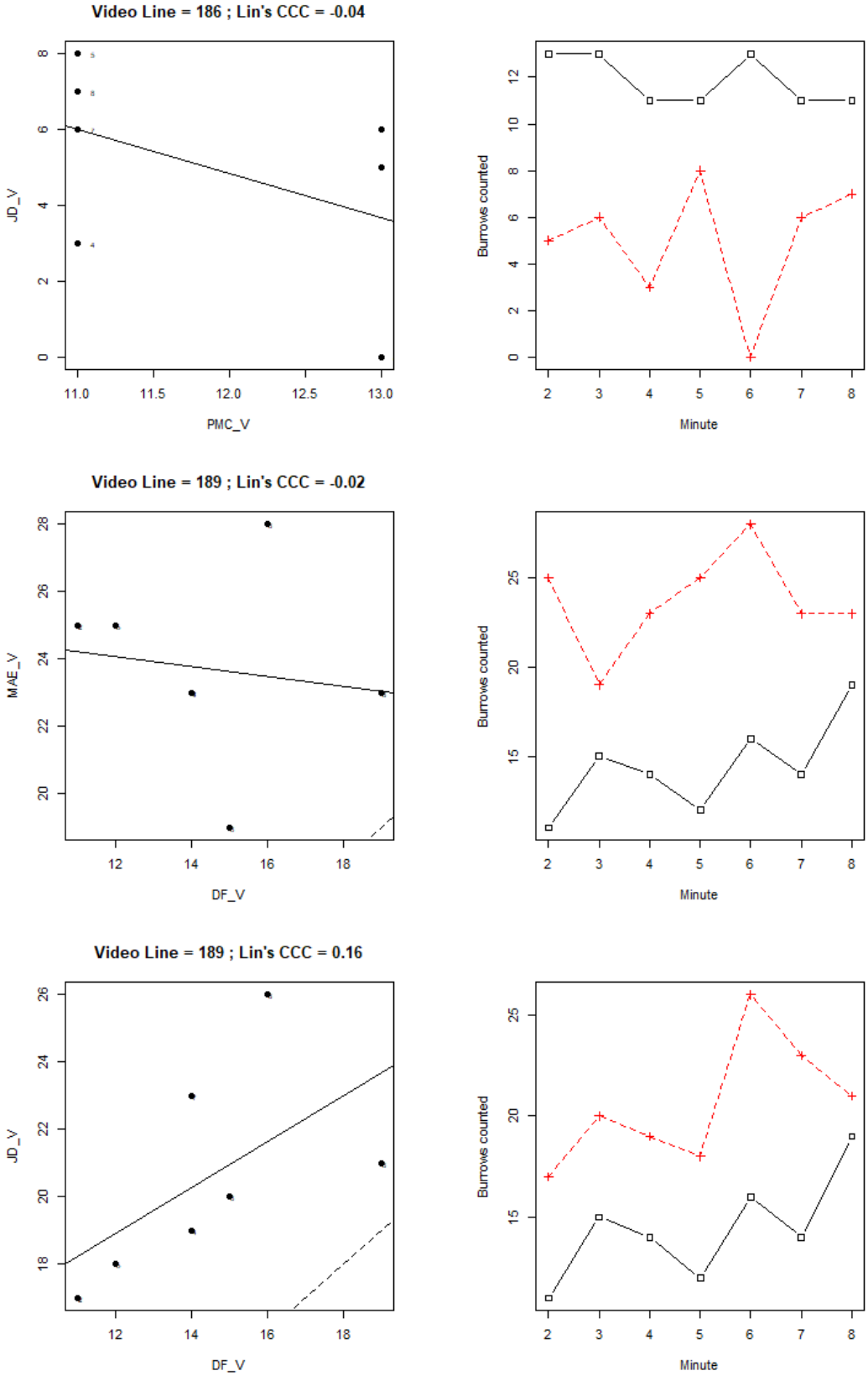

Video Line = 168 ; Lin's CCC = 0.39
JD_V
MAE_V
Burrows counted
Minute
Video Line = 178 ; Lin's CCC = 0.14
JW_V
OH_V
Burrows counted
Minute
Video Line = 178 ; Lin's CCC = 0.96
JD_V
OH_V
Burrows counted
Minute

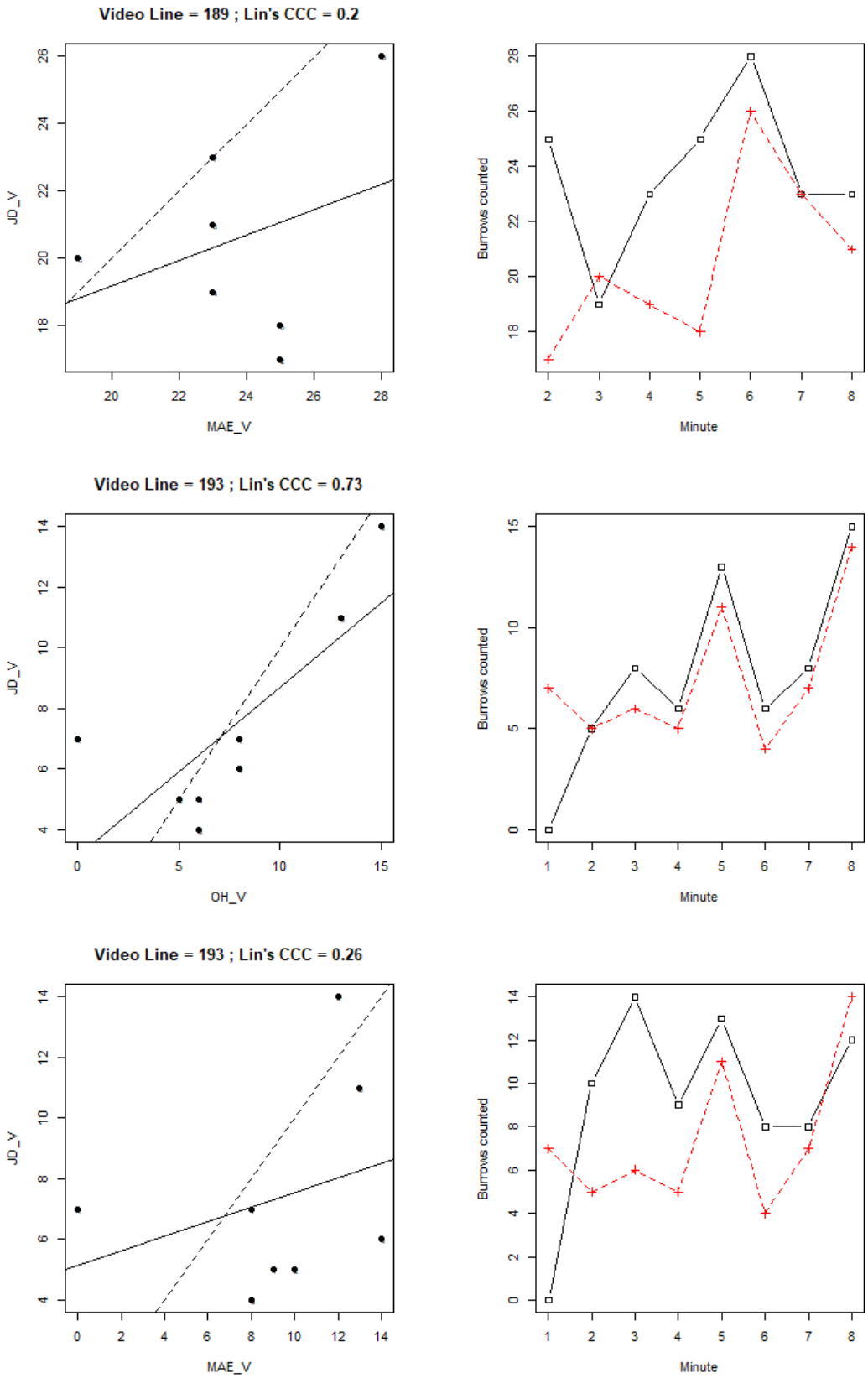

Video Line = 178 ; Lin's CCC = 0.15
JD_V
JW_V
Burrows counted
Minute

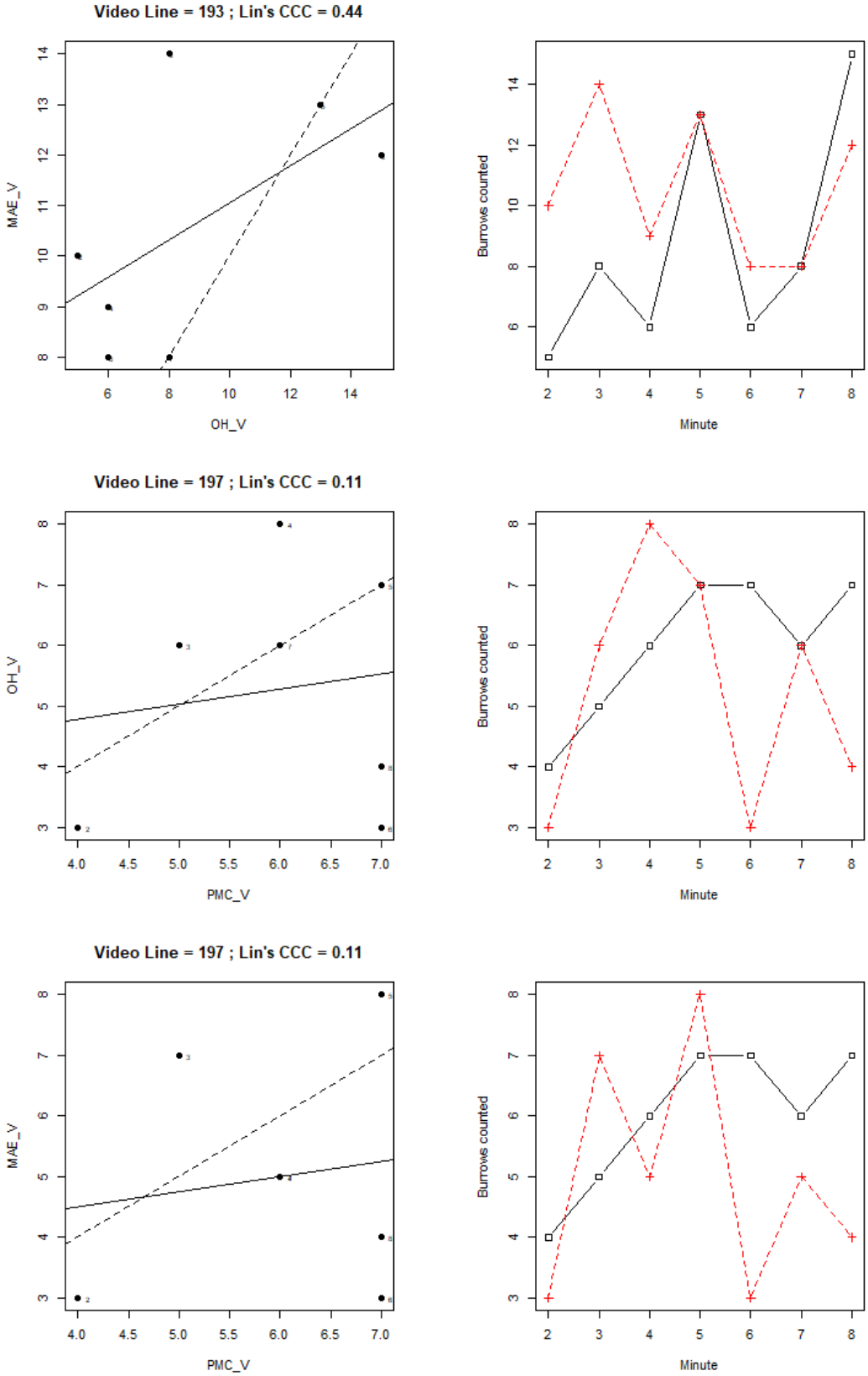

Video Line = 181 ; Lin's CCC = 0.14
MAE_V
DF_V
Burrows counted
Minute


Video Line = 181 ; Lin's CCC = -0.02
JD_V
DF_V
Burrows counted
Minute

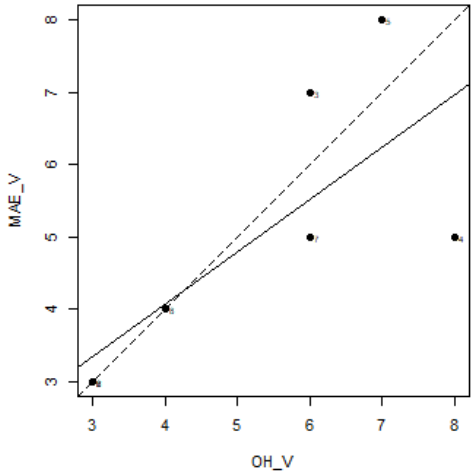

Video Line = 181 ; Lin's CCC = 0.36
JD_V
MAE_V
Burrows counted
Minute
Video Line = 186 ; Lin's CCC = -0.03
PMC_V
DF_V
Burrows counted
Minute
Video Line = 186 ; Lin's CCC = 0.01
JD_V
DF_V
Burrows counted
Minute

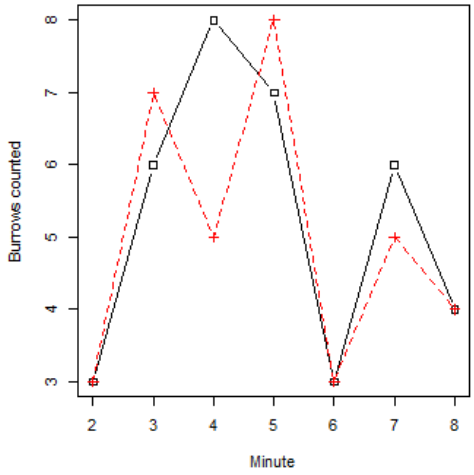

Video Line = 186 ; Lin's CCC = -0.04
JD_V
PMC_V
Burrows counted
Minute
Video Line = 189 ; Lin's CCC = -0.02
MAE_V
DF_V
Burrows counted
Minute
Video Line = 189 ; Lin's CCC = 0.16
JD_V
DF_V
Burrows counted
Minute


Video Line = 189 ; Lin's CCC = 0.2
JD_V
MAE_V
Burrows counted
Minute
Video Line = 193 ; Lin's CCC = 0.73
JD_V
OH_V
Burrows counted
Minute
Video Line = 193 ; Lin's CCC = 0.26
JD_V
MAE_V
Burrows counted
Minute

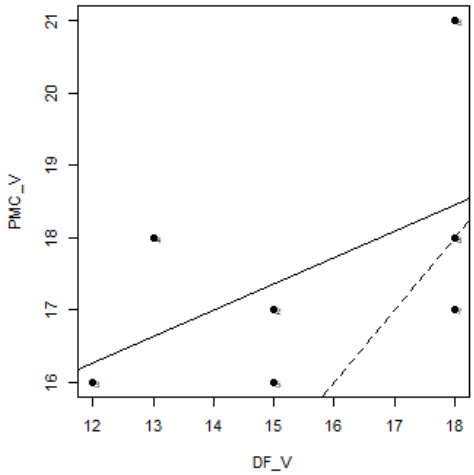

Video Line = 193 ; Lin's CCC = 0.44
MAE_V
OH_V
Burrows counted
Minute
Video Line = 197 ; Lin's CCC = 0.11
OH_V
PMC_V
Burrows counted
Minute
Video Line = 197 ; Lin's CCC = 0.11
MAE_V
PMC_V
Burrows counted
Minute

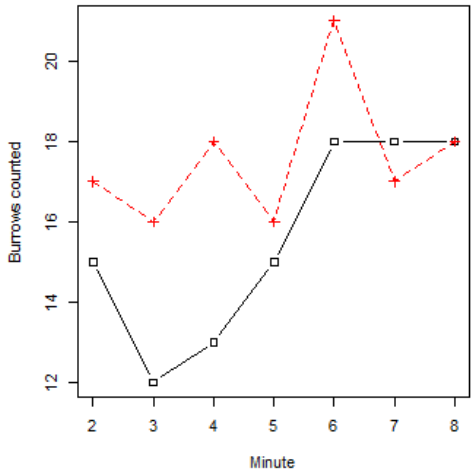
Video Line = 197 ; Lin's CCC = 0.74



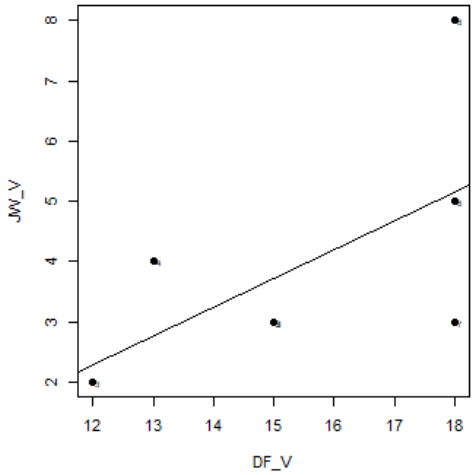


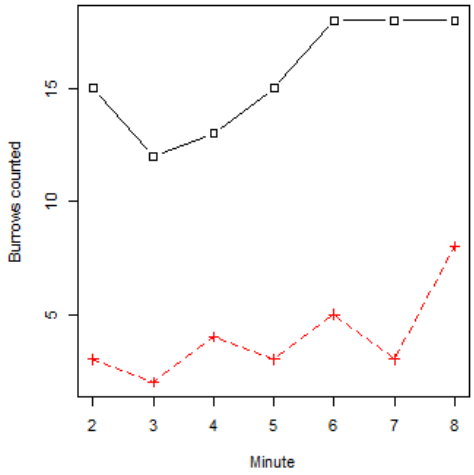
Video Line = 203 ; Lin's CCC = 0.33

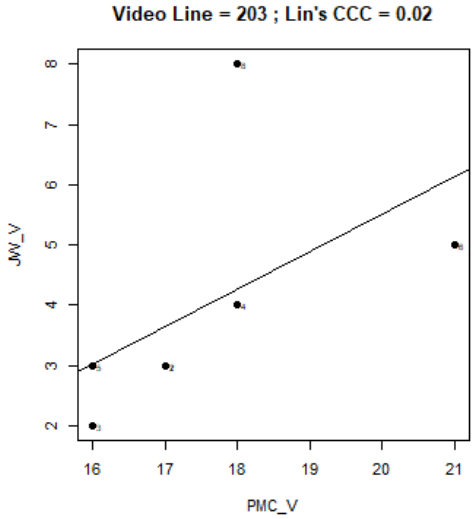


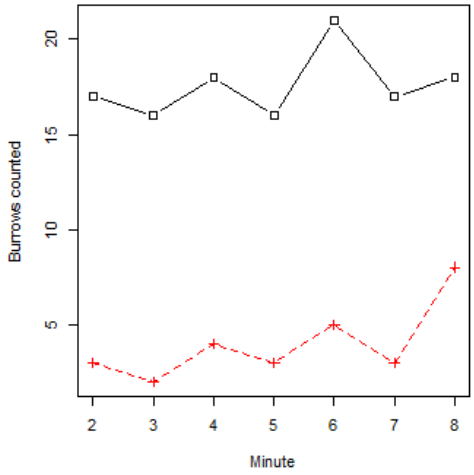


Video Line = 203 ; Lin's CCC = 0.04






Video Line = 203 ; Lin's CCC = 0.02
JW_V
PMC_V
2
3
4
5
6
7
8
16
17
18
19
20
21


Burrows counted
Minute
5
10
15
20
2
3
4
5
6
7
8

4.9 Lin's CCC results

- 1/16 station passed LINS CCC thresholds with the first 2 counters.
- 15/16 stations require a third review, where 11 of these stations all 3 reviewers data were used to calculate final density. This is the standard practice on UWTV surveys by the Marine Institute.

Now we will remove the 3rd reviewer from the other stations (4 stations).

```
## stn 150 OH_V stn 178 JW_V stn 193 MAE_V stn 197 PMC_V

Recounts1 <- Recounts[-which(Recounts$Video_Line_Name == 150 & Recoun
ts$VideoOperatorID ==
    31), ]
Recounts1 <- Recounts1[-which(Recounts1$Video_Line_Name == 178 & Reco
unts1$VideoOperatorID ==
    32), ]
Recounts1 <- Recounts1[-which(Recounts1$Video_Line_Name == 193 & Reco
unts1$VideoOperatorID ==
    33), ]
Recounts1 <- Recounts1[-which(Recounts1$Video_Line_Name == 197 & Reco
unts1$VideoOperatorID ==
    15), ]
```

4.7 Comparison by station: 2017 original counts vs. validation counts

```
# calculate average count per station for historical review
rec.1 <- Recounts1 %>% group_by(Video_Line_Name, Minute) %>% summaris
e(ct = mean(BurrowCount))
val.data <- rec.1 %>% group_by(Video_Line_Name) %>% summarise(av.coun
t = sum(ct))
val.data$method <- "review"

# next extract sea counts (original data from 2017)
orig.data <- subset(rec, !VideoOperatorID %in% c(12, 15, 31, 32, 33,
34))

orig.minute <- with(orig.data, aggregate(BurrowCount, by = list(Minut
e,
    Video_Line_Name), FUN = mean))
names(orig.minute) <- c("Minute", "Video_Line_Name", "ct")
orig.data <- with(orig.minute, aggregate(ct, by = list(Video_Line_Nam
e),
    FUN = sum))
names(orig.data) <- c("Video_Line_Name", "av.count")
orig.data$method <- "original"

final2017 <- rbind(orig.data, val.data)

# merge both datasets
wide <- merge(orig.data, val.data, by = "Video_Line_Name")
wide <- wide[, -c(3, 5)]
wide <- rbind(wide, c("Total", colSums(wide)[2:3]))
names(wide) <- c("stn", "orig.count", "valid.count")
wide[, 2] <- as.numeric(wide[, 2])
wide[, 3] <- as.numeric(wide[, 3])
wide$perc.change <- 100 * with(wide, (valid.count/orig.count) - 1)
```

```
knitr::kable(wide[, 1:4], caption = paste0("2017 FU20-21 UWTV Origina
l survey counts,",
    " Validation review counts and difference in percentage for each
of the",
    " Reviewed stations and in total"))
```

Table 10. 2017 FU20-21 UWTV Original survey counts, Validation review counts and difference in percentage for each of the Reviewed stations and in total

stn	orig.count	valid.count	perc.change
126	72.500000	68.000000	-6.2068965
138	54.000000	48.666667	-9.8765432
148	115.000000	78.333333	-31.8840580
150	96.000000	47.500000	-50.5208333
156	39.000000	28.000000	-28.2051282
158	128.500000	65.333333	-49.1569390
160	52.333333	53.666667	2.5477707
165	76.000000	33.666667	-55.7017544
168	145.000000	127.666667	-11.9540230
178	197.500000	99.500000	-49.6202532
181	72.000000	55.333333	-23.1481482
186	66.500000	74.333333	11.7794486
189	248.500000	137.000000	-44.8692153
193	68.000000	63.500000	-6.6176471
197	48.500000	36.000000	-25.7731959
203	114.000000	86.666667	-23.9766082
Total	1593.333333	1103.166667	-30.7635983

```
ggplot(final2017, aes(x = as.factor(Video_Line_Name), y = av.count, f
ill = method,
    col = method)) + geom_bar(stat = "identity", position = position_
dodge()) +
    xlab("Station ID") + ylab("count") + theme_bw()
```

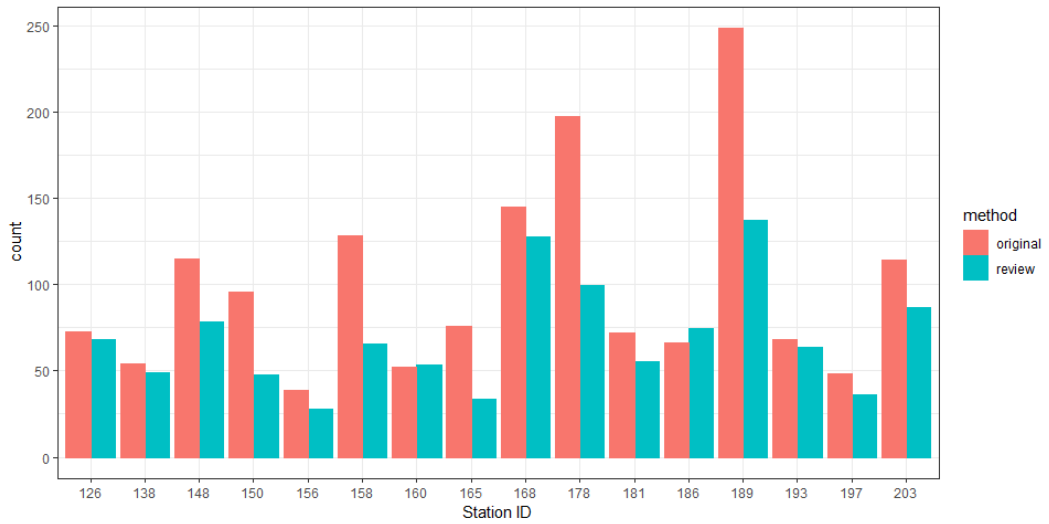


Figure 14: Bar plot showing 2017 original counts and the validation counts

4.8 Violin plot of the 2017 original counts and the validation counts

```
final2017 <- cbind(final2017, wide[-nrow(wide),])

ggplot(final2017,aes(x=as.factor(method),y=av.count))+
  geom_violin(aes(group=method,colour=method,fill=method),alpha=0.5,
              kernel="rectangular")+  # passes to stat_density, makes
violin rectangular
  geom_boxplot(aes(group=method), width=.2)+
  stat_summary(fun.y=mean, geom="line", colour="blue", aes(group=1))
+
  xlab("method")+
  ylab("av.count")+
  theme_bw()+
  theme(legend.position = "none")
```

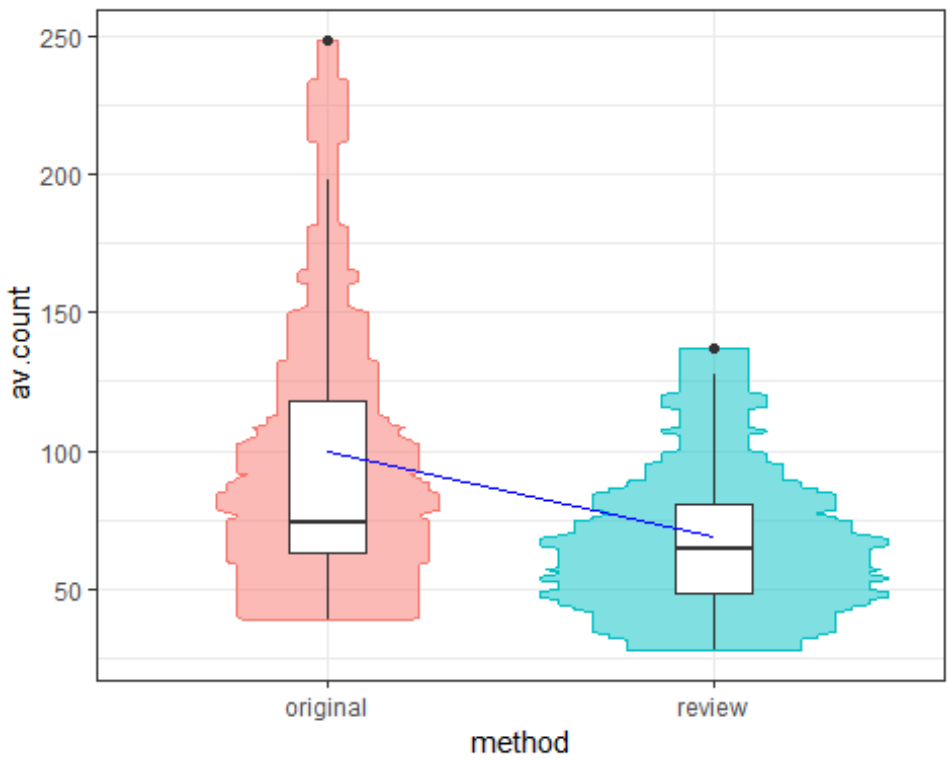


Figure 15: Violin and box plot of counts distributions of 2017 original counts and validation counts. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers

5 2017: KRIGING

We load the data and select the review counts for the 16 reviewed stations in 2018. We created the local access queries to generate the final data for input. We checked the local queries sql queries and R queries to make sure they do the same.

5.1 Previous step for getting the coordinates of the original stations in 2017

```
## Code to connect to live UWTV_SURVEY database on MI Network
VMFSSSQL0
channel <- odbcDriverConnect("Driver=SQL Server; Server=VMFSSSQL02;
Database=UWTV_Surveys; ")
```

```
nep.all <- sqlQuery(channel, "select * from dbo.Summary_Full-
WorkUp_Vw")
close(channel)

nep <- subset(nep.all, Year == 2017 & Ground == "Labadie")
nep1 <- nep[, c(2, 5, 12, 13)]  # we create nep1 to join later to the
validation counts
nep1$StationNumber <- as.numeric(as.character(nep1$StationNumber))
```

5.2 Run the queries in the local survey database to calculate final data for kriging

```
setwd("N:\\Surveys\\UWTV SURVEYS FU2022 CELTIC SEA\\Historical re-
view Labadie 2017\\Kriging")

# The database must be CLOSED to run the queries

channel <- odbcConnectAccess(paste0("N:/Surveys/UWTV SURVEYS FU2022
CELTIC SEA/",
    "Historical review Labadie 2017/Final Data/NEPHROPS_MULTI-
LOG_CV17018_Labadie"))
# Query 1
StopTime <- sqlQuery(channel, "
SELECT Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoOp-
eratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime
FROM Recounts
GROUP BY Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.Video-
OperatorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime
HAVING (((Recounts.StopTime)>=#12/30/1899# And (Recounts.Stop-
Time)<=#12/30/1899 0:15:0#)
AND ((Recounts.StartTime)>=#12/30/1899# And (Recounts.Start-
Time)<=#12/30/1899 0:15:0#));
         ")

# Query 2
sqlDrop(channel, "RecountNotUsuable")
sqlQuery(channel, "
SELECT Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.VideoOp-
eratorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime,
Recounts!StartTime-Recounts!StopTime AS DifferenceNumber,
Recounts!StartTime-Recounts!StopTime AS DifferenceTime INTO Recount-
NotUsuable
FROM Recounts
GROUP BY Recounts.SurveyID, Recounts.Video_Line_Name, Recounts.Video-
OperatorID,
Recounts.Minute, Recounts.StopTime, Recounts.StartTime,
Recounts!StartTime-Recounts!StopTime, Recounts!StartTime-Re-
counts!StopTime
HAVING (((Recounts.StopTime)>=#12/30/1899# And (Recounts.Stop-
Time)<=#12/30/1899 0:15:0#)
AND ((Recounts.StartTime)>=#12/30/1899# And (Recounts.Start-
Time)<=#12/30/1899 0:15:0#));
         ")

## character(0)
```

```
StopTime1min <- sqlFetch(channel, "RecountNotUsuable")

# Query 3
IdentifyUnusuables <- sqlQuery(channel, "
SELECT RecountNotUsuable.SurveyID, RecountNotUsuable.Video_Line_Name,
RecountNotUsuable.VideoOperatorID, RecountNotUsuable.Minute, RecountN
otUsuable.StopTime,
RecountNotUsuable.StartTime, RecountNotUsuable.DifferenceTime,
RecountNotUsuable.DifferenceNumber, IIf([DifferenceNumber]>=0.0003472
22222222222,1000)
AS Unusuable
FROM RecountNotUsuable;
         ")

# Query 4
sqlDrop(channel, "UnusuableRecountMinsTable")
sqlQuery(channel, "
SELECT [Qry3-IdentifyUnusuablesForRecounts].SurveyID,
[Qry3-IdentifyUnusuablesForRecounts].Video_Line_Name,
[Qry3-IdentifyUnusuablesForRecounts].Minute,
[Qry3-IdentifyUnusuablesForRecounts].Unusuable
INTO UnusuableRecountMinsTable
FROM [Qry3-IdentifyUnusuablesForRecounts]
WHERE ((([Qry3-IdentifyUnusuablesForRecounts].Unusuable) Like 1000))
GROUP BY [Qry3-IdentifyUnusuablesForRecounts].SurveyID,
[Qry3-IdentifyUnusuablesForRecounts].Video_Line_Name,
[Qry3-IdentifyUnusuablesForRecounts].Minute, [Qry3-IdentifyUnusuables
ForRecounts].Unusuable;
        ")

## character(0)

MakeTable <- sqlFetch(channel, "UnusuableRecountMinsTable")

# Query 5
sqlDrop(channel, "Recounts-Clean")
sqlQuery(channel, "
SELECT Recounts.RecountID, Recounts.Video_Line_Name, Recounts.SurveyI
D,
Recounts.VideoOperatorID, Recounts.Minute, Recounts.BurrowCount,
Recounts.NephropsIn, Recounts.NephropsOut, Recounts.StopTime,
Recounts.StartTime, UnusuableRecountMinsTable.Unusuable INTO [Recount
s-Clean]
FROM Recounts LEFT JOIN UnusuableRecountMinsTable ON
(Recounts.Minute = UnusuableRecountMinsTable.Minute) AND
(Recounts.SurveyID = UnusuableRecountMinsTable.SurveyID) AND
(Recounts.Video_Line_Name = UnusuableRecountMinsTable.Video_Line_Name
)
GROUP BY Recounts.RecountID, Recounts.Video_Line_Name, Recounts.Surve
yID,
Recounts.VideoOperatorID, Recounts.Minute, Recounts.BurrowCount,
Recounts.NephropsIn, Recounts.NephropsOut, Recounts.StopTime,
Recounts.StartTime, UnusuableRecountMinsTable.Unusuable
HAVING (((UnusuableRecountMinsTable.Unusuable) Is Null));
        ")

## character(0)

Recounts_clean <- sqlFetch(channel, "Recounts-Clean")
```

5.3 Remove banana stations (outside FU20-21) and counters who failed Lin's CCC

```
# Check station numbers
length(unique(Recounts_clean$Video_Line_Name))

## [1] 88

unique(Recounts_clean$Video_Line_Name)

##  [1] 188 179 174 169 168 157 149 142 150 151 152 204 167 164 158 1
63 162
## [18] 161 126 120 121 127 122 128 133 134 135 136 143 132 141 148 1
56 155
## [35] 147 124 125 131 123 130 129 166 165 170 171 172 176 175 180 1
81 182
## [52] 183 184 139 140 146 138 145 177 173 185 186 195 194 137 144 1
54 153
## [69] 159 160 191 190 189 178 187 196 300 301 197 198 202 205 192 1
93 199
## [86] 200 201 203

# Remove Banana stations
Recounts_clean <- Recounts_clean[!Recounts_clean[, "Video_Line_Name"]
%in%
    c(300, 301), ]

# remove counters from Lins check

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    150 & Recounts_clean$VideoOperatorID == 31), ]

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    178 & Recounts_clean$VideoOperatorID == 32), ]

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    193 & Recounts_clean$VideoOperatorID == 33), ]

Recounts_clean <- Recounts_clean[-which(Recounts_clean$Video_Line_Nam
e ==
    197 & Recounts_clean$VideoOperatorID == 15), ]


# Check station numbers
length(unique(Recounts_clean$Video_Line_Name))

## [1] 86

unique(Recounts_clean$Video_Line_Name)

##  [1] 188 179 174 169 168 157 149 142 150 151 152 204 167 164 158 1
63 162
## [18] 161 126 120 121 127 122 128 133 134 135 136 143 132 141 148 1
56 155
## [35] 147 124 125 131 123 130 129 166 165 170 171 172 176 175 180 1
81 182
## [52] 183 184 139 140 146 138 145 177 173 185 186 195 194 137 144 1
54 153
```

```
## [69] 159 160 191 190 189 178 187 196 197 198 202 205 192 193 199 2
00 201
## [86] 203
```

5.4 Switch to use the review station data

```
# reading the workplan with the reviewed 14 stations
workplan <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SE
A/",
    "Historical review Labadie 2017/final data/2017_QC_FU2021_WorkPla
n.csv"),
    colClasses = "character")
workplan <- workplan[, c("Station", "First", "Second")]

# select the sea counts from the other 55 stations
sea_dat <- Recounts_clean[!Recounts_clean[, "Video_Line_Name"] %in% w
orkplan$Station,
    ]
# sea_dat <- sea_dat[!sea_dat[,'VideoOperatorID'] %in% c(29:34),]

# select the validation counts from the reviewed 14 stations
val_dat <- Recounts_clean[Recounts_clean[, "Video_Line_Name"] %in% wo
rkplan$Station,
    ]
validation_counters <- c(12, 15, 31, 32, 33, 34)
val_dat <- val_dat[val_dat[, "VideoOperatorID"] %in% validation_count
ers,
    ]

# combine sea counts and validation counts

Recounts_clean <- rbind(sea_dat, val_dat)

Recounts_AvgMin <- with(Recounts_clean, aggregate(BurrowCount, by = l
ist(Minute,
    Video_Line_Name), FUN = mean))
colnames(Recounts_AvgMin) <- c("Minute", "StationNumber", "Average")

DOG <- sqlFetch(channel, "DistanceOverGroundFinal")
close(channel)

dat <- left_join(Recounts_AvgMin, DOG, by = c("StationNumber", "Minut
e"))
dat$Area <- dat$CountedDistance * 0.75


dat1 <- dat %>% group_by(StationNumber) %>% summarise(dist = sum(Coun
tedDistance),
    area = sum(Area), burrowcount = sum(Average)) %>% mutate(density
= burrowcount/area)

nep2 <- left_join(dat1, nep1, by = c("StationNumber"))
nep2$AdjustedBurrowDensity <- nep2$density/1.26
```

5.5 Begin krigging analysis

```
nep2 <- nep2[, c("Year", "Ship_Mid_Longitude", "SHIP_Mid_Latitude", "
AdjustedBurrowDensity")]
surv.yr <- nep2$Year[1]
mt <- paste(surv.yr, "FU20-21 UWTV Density_Validation")
```

```
data.db <- db.create(nep2, flag.grid = FALSE, ndim = 2, autoname = F
)
# Data management (define lat/lon)
data.db <- db.locate(data.db, 3:4, loctype = "x")
# data.db@locators[1] <- 'rank' data.db@locators[2] <- 'Year' Data
# management (define density)
data.db <- db.locate(data.db, 5, loctype = "z")
projec.define(projection = "mean", db = data.db)

##
## Parameters for projection
## -------------------------
## Projection is switched ON
## Use 'projec.define' to modify previous values

projec.toggle(mode = 0)
```

5.5.1 Load a polygon delimiting the research survey domain and create polygon structure

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2017/Kriging")
pol.FU2021 <- read.table("pol.Labadie.IBP.csv", header = T, sep = ","
)
poly <- polygon.create(x = pol.FU2021$x, y = pol.FU2021$y)

db.poly <- polygon.create(x = pol.FU2021[, 1], y = pol.FU2021[, 2], p
olygon = NA)
europa <- read.table("europa.txt", header = T)
plot(data.db, title = mt, inches = 5, asp = 1/cos(mean(db.extract(dat
a.db,
    "x1")) * pi/180), xlim = c(-9.5, -6.65), ylim = c(49.5, 51.2))
plot(poly, col = 8, add = T)
polygon(europa, col = 8)
box()
```

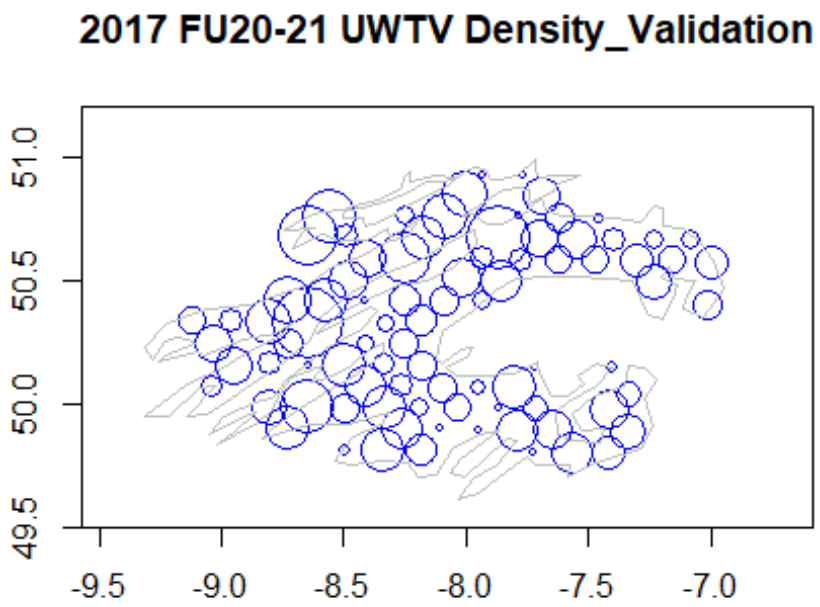


Figure 16: 2017 FU20-21 UWTV Density validation plot with polygon delimiting the research survey domain

5.6 Visualizing the dataset (in projected space based on the mean of the points)

Then checking for points inside and outside the polygon. Ensure data are same as that in 2016.

```
projec.define(projection = "mean", db = data.db)

##
## Parameters for projection
## -------------------------
## Projection is switched ON
## Use 'projec.define' to modify previous values

projec.toggle(mode = 1)

##
## Parameters for projection
## -------------------------
## Projection is switched ON
## Use 'projec.define' to modify previous values

plot(data.db, title = mt, inches = 5, asp = 1, xlim = c(-50, 50), yli
m = c(-50,
    50))
plot(poly, col = 8, add = T)
europa.p <- projec.operate(x = europa$x, y = europa$y)
polygon(europa.p, col = 8)
box()
```

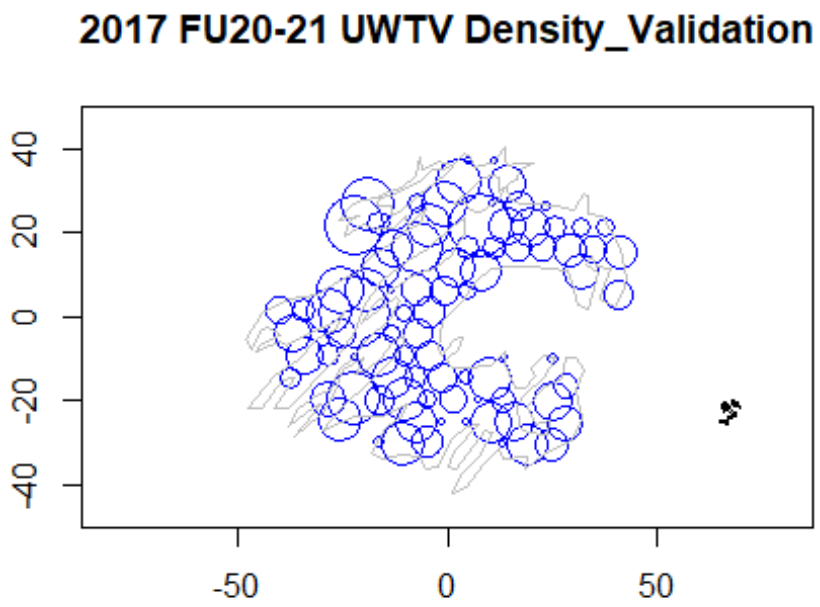


Figure 17: 2017 FU20-21 UWTV Density validation plot with polygon delimiting the research survey domain. Other projection

```
db.c1 <- data.db
# select points inside polygon
db.c1 = db.polygon(db.c1, db.poly)
cat("nb points: ", db.c1$nech, " ; outside polygon: ", sum(!db.c1@ite
ms$Polygon),
    "\n")

## nb points:  86  ; outside polygon:  0
```

5.7 Getting summary statistics for inside the polygon

```
# mean, variance, histogramme of data inside polygon
zm <- mean(db.c1[, 5][db.c1[, 6]], na.rm = T)
zv <- var(db.c1[, 5][db.c1[, 6]], na.rm = T) * (sum(db.c1[, 6], na.rm
= T) -
    1)/sum(db.c1[, 6], na.rm = T)
cat("mean: ", zm, "    var: ", zv, "   cv: ", sqrt(zv)/zm, "\n")

## mean:  0.41757863     var:  0.061231729    cv:  0.5925841

hist(db.c1[, 5][db.c1[, 6]], nclass = 20, xlab = "burrow density n/m²
",
    main = mt)
```

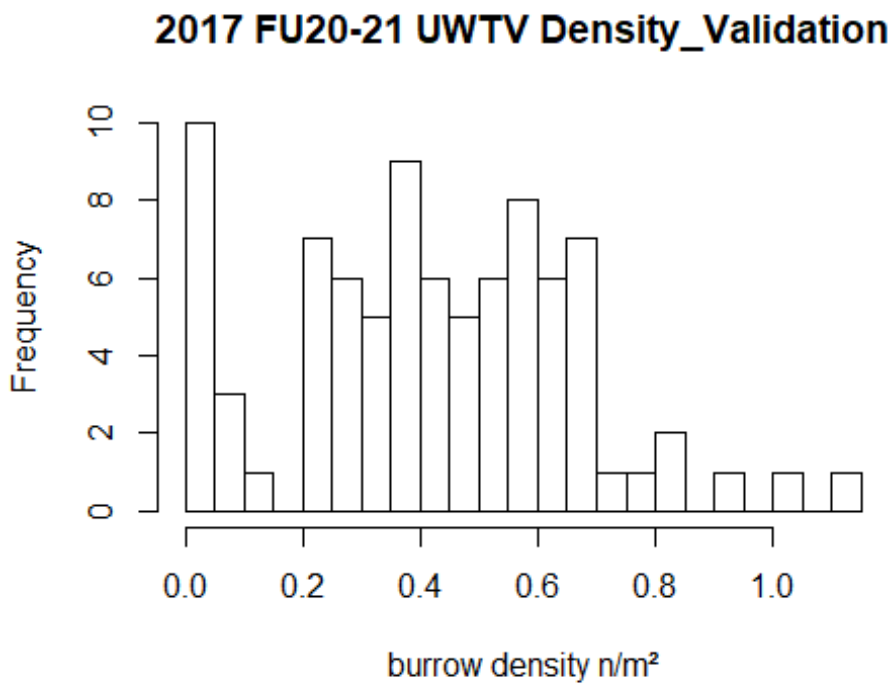


Figure 18: 2017 FU20-21 UWTV Density validation barplot

5.8 Setting up the experimental variogram and plotting the points

Fitting an experimental variogram to the pairs.

```
Lag = 2.2
Nlag = 19
vg1 = vario.calc(db.c1, lag = Lag, nlag = Nlag)
vario.plot(vg1, npairpt = 1, xlab = "Distance", ylab = "Variogram", p
ch = 9,
    cex = 0.001, col = "grey", title = mt)
```

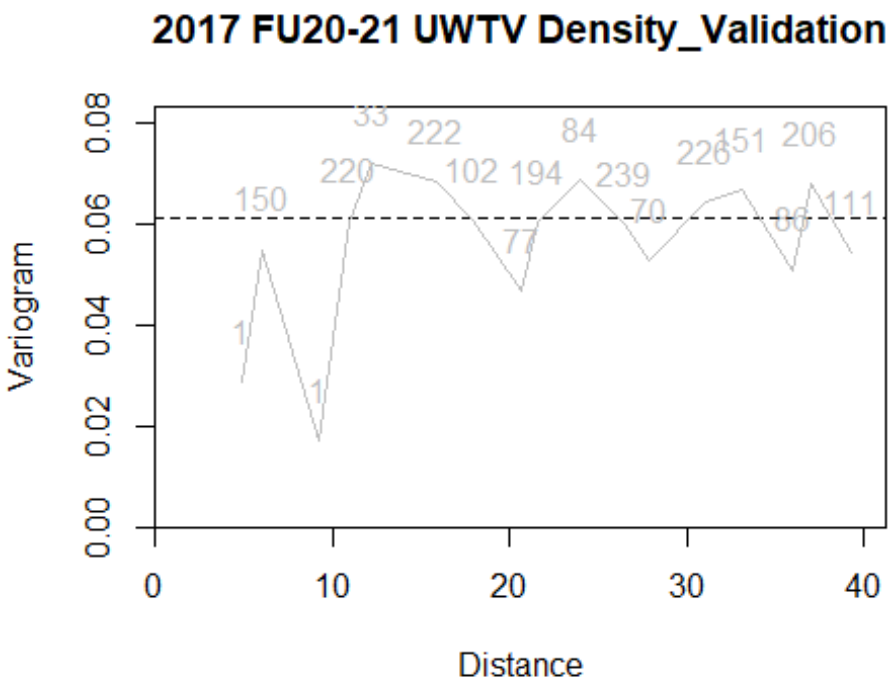


Figure 19: 2017 FU20-21 UWTV Density validation variogram

```
vg.fit = model.auto(vg1, struc = c("Spherical"), title = paste(mt, "a
uto fit Spherical"),
    xlab = "Distance", ylab = "variogram")
```

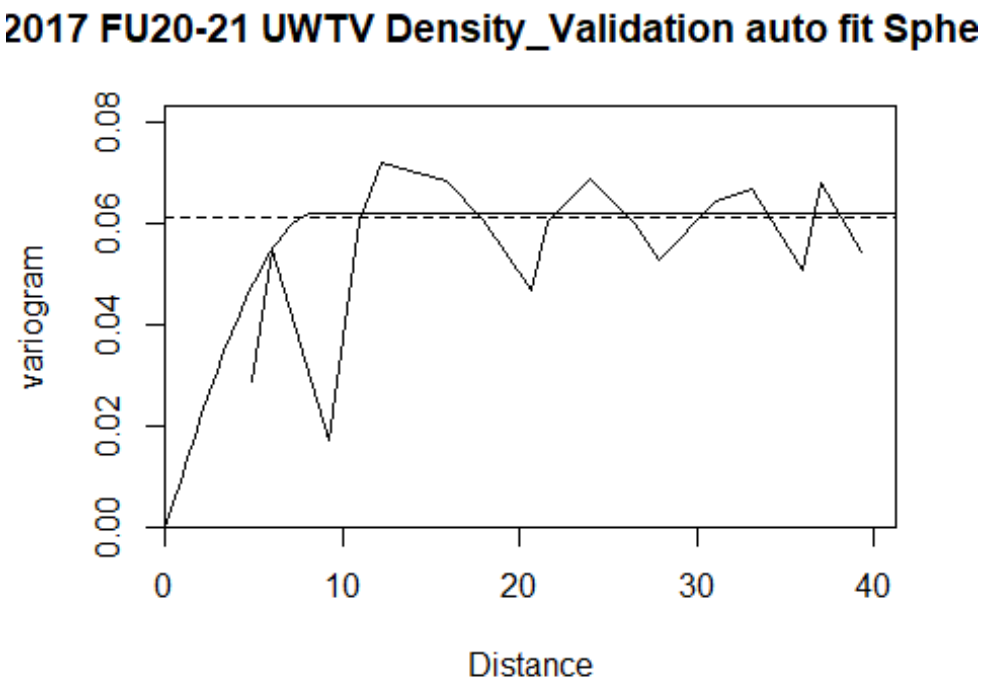


Figure 20: 2017 FU20-21 UWTV Density validation spherical variogram

```
vg.fit

##
## Model characteristics
## =====================
## Space dimension              = 2
## Number of variable(s)        = 1
## Number of basic structure(s) = 1
## Number of drift function(s)  = 1
## Number of drift equation(s)  = 1
##
## Covariance Part
## ---------------
## - Spherical
##   Range       =      8.521
##   Sill        =      0.062
## Total Sill    =      0.062
##
## Drift Part
## ----------
## Universality Condition
```

5.9 Grid the data

This step involves making a grid of points within the domain area. This grid is used for the modelled surface. A grid of 100X100 points was choosed because it was similiar to the previous methodology in SURFER. The grid is plotted along with the domain boundary and bubbles of density.

```
setwd("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/Historical review La
badie 2017/Kriging")

poldat <- read.table("pol.Labadie.IBP.csv", header = T, sep = ",")

gnx = 100
gny = 100
gx0 = min(poldat$x)
gx1 = max(poldat$x)
gy0 = min(poldat$y)
gy1 = max(poldat$y)
gdx = (gx1 - gx0)/gnx
gdy = (gy1 - gy0)/gny
gd.disc = db.create(flag.grid = T, x0 = c(gx0, gy0), dx = c(gdx, gdy)
,
    nx = c(gnx, gny))
gd.disc = db.polygon(gd.disc, db.poly)
plot(gd.disc, pch = 3, col = 1)
plot(db.c1, add = T, pch = 21)
plot(db.poly, add = T)
```

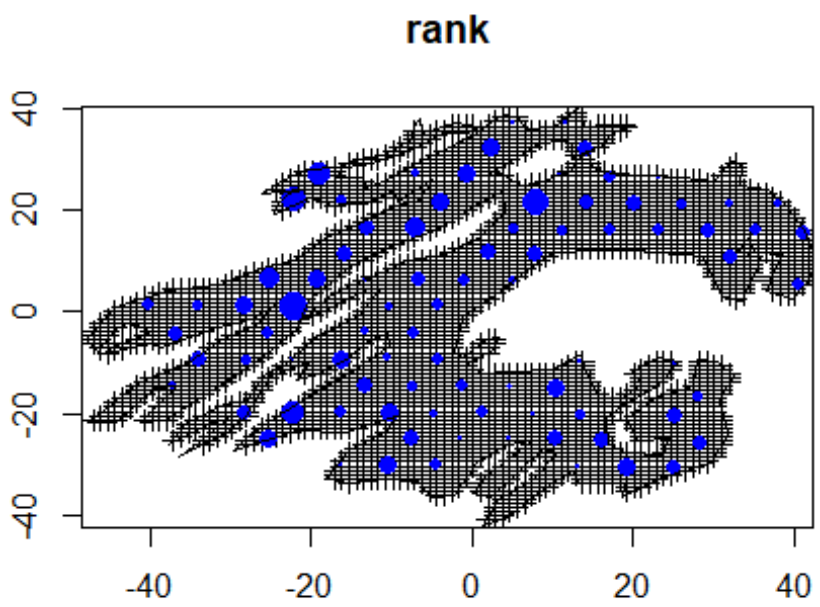


Figure 21: 2017 FU20-21 UWTV grid map with densities per station

5.9.1 Calculate the mean burrow density and geostistical CV for the grid

This mean and CV is different from the krigging estimates calculated later but they should be fairly close for this type of dataset.

```
# calculation of CVV
cvv = model.cvv(polygon = db.poly, model = vg.fit, ndisc = c(gnx, gny
))
# Global estimate = arithmetic mean. s2est=cvv+cxx-2*cxv
cxx = model.cxx(db1 = db.c1, model = vg.fit)
cxv = model.cxv(db = db.c1, polygon = db.poly, model = vg.fit, ndisc
= c(gnx,
    gny))
sse = sqrt(cvv + cxx - 2 * cxv)
cat("arith.mean: ", round(zm, 5), " CV.geo: ", round(sse/zm, 5), "\n
")

## arith.mean:  0.41758  CV.geo:  0.04
```

5.10 Kriging using the fitted variogram

Neighbourhood weighting is not needed given the properties of this dataset (i.e. <50 observations which are fairly homogoneous and strongly auto-corellated).

The krigged surface and the error structure is plotted for you to take a look at.

The grid is saved for plotting purposes later.

The mean z estimate from kriging is multiplied by the polygon surface

9978.3285978km² to calculate the total abundance.

The summary object contains all the salient infomation for the final results

```
global.ma = global(dbin = db.c1, dbout = gd.disc, model = vg.fit, uc
= c("1"),
    polygon = db.poly, calcul = "krige", flag.polin = T, flag.wgt = F
,
    ivar = 1, verbose = 1)

## Global estimation kriging
## ========================
## Total number of data              = 86
## Number of active data             = 86
## Number of variables               = 1
## Cvv                               = 0.000717
## Estimation by kriging             = 0.425966
## Lagrange Parameter #1             = -0.000297
## Estimation St. Dev. of the mean   = 0.016175
## CVgeo                             = 0.037973
##
## Surface                           = 2909.215126
## Q (Estimation * Surface)          = 1239.226906

toto <- db.create(x1 = pol.FU2021[, 1], x2 = pol.FU2021[, 2])
grid <- db.grid.init(toto, nodes = 100)  # number of nodes if related
with the fining of the grid
# when using all data as neighbours
uniquenei <- neigh.init(2, 0)

## The function 'neigh.init'will soon become obsolete
## Please use function 'neigh.create' instead (same arguments)

kri <- kriging(dbin = db.c1, db.polygon(grid, poly), vg.fit, uniquene
i)
plot(kri, col = tim.colors(200), asp = 1, xlim = c(-50, 50), ylim = c
(-50,
    50), name.image = "Kriging.AdjustedBurrowDensity.estim")
plot(poly, col = 22, add = T)
plot(db.c1, col = "black", add = T)
```

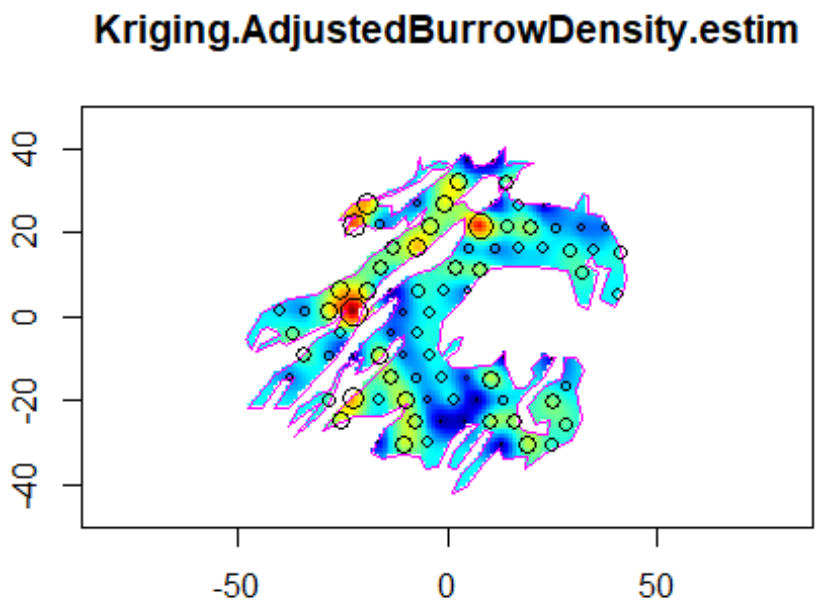


Figure 22: 2017 FU20-21 UWTV contour map for the adjusted burrow density estimates

```
plot(kri, col = tim.colors(10), asp = 1, xlim = c(-50, 50), ylim = c(
-50,
    50), name.image = "Kriging.AdjustedBurrowDensity.stdev")  #map th
e estimation variance
plot(poly, col = 22, add = T)
plot(db.c1, col = 1, add = T)
```

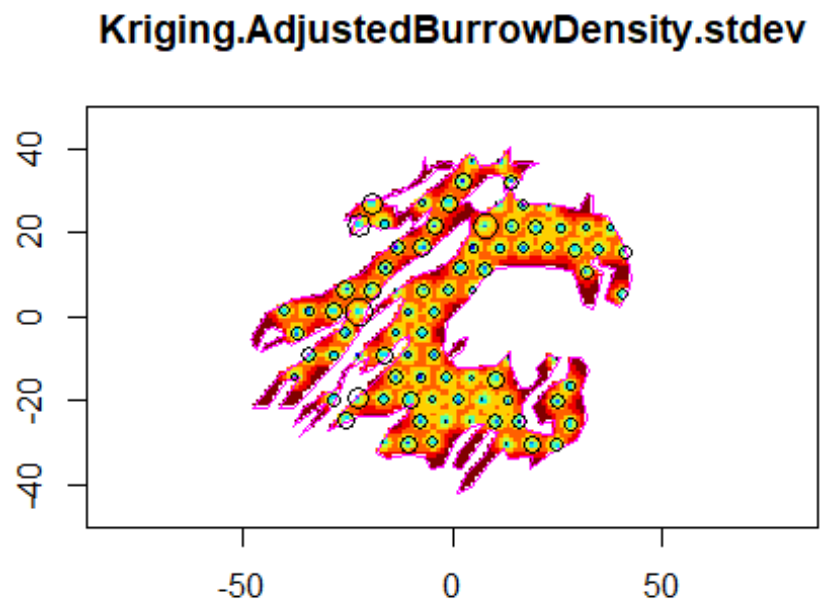


Figure 23: 2017 FU20-21 UWTV contour map for the adjusted burrow density standard deviations

```
ggin <- as.data.frame(kri@items)

write.csv(ggin, file = paste0("ggin", surv.yr, "_Historical_review.cs
v"))

# Survey abundance estimate in numbers (millions)
abun <- global.ma$zest * poly$surface * 1.852^2
```

5.11 Results

```
# read in summary file from surfer calculation
k.sum <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC SEA/2
018 Labadie/",
    "Kriging/Labadie_Summary_ADG_2018.csv"))

k.sum <- k.sum[-1]
k.sum <- subset(k.sum, Year < 2018)

k.sum <- rbind(k.sum, data.frame(Year = nep2$Year[1], Ground = "FU202
1",
    mean = zm, N = db.c1$nech, sd = zv/zv^0.05, se = sse, ciMult = N
A,
    ci = abun * global.ma$cv * 1.96, area = poly$surface * 1.852^2, a
bund = abun,
    upper = abun + abun * global.ma$cv * 1.96, lower = abun - abun *
global.ma$cv *
        1.96, CViid = zv/zm, meanGeo = global.ma$zest, CVgeo = global
.ma$cv))

k.sum$method <- c(rep("ORIGINAL COUNTS", 5), "HISTORICAL REVIEW")
```

```
k.sum2017 <- k.sum[5:6, ]


knitr::kable(k.sum2017[, c(1:2, 16, 3:6)], caption = paste0("2017 FU2
0-21 UWTV",
    " Summary results of the kriging from the Original survey counts
and",
    " from the Validation review counts. Density and abundance estima
tes"))
```

Table 11. 2017 FU20-21 UWTV Summary results of the kriging from the Original survey counts and from the Validation review counts. Density and abundance estimates

	Year	Ground	method	mean	N	sd	se
5	2017	FU2021	ORIGINAL COUNTS	0.44000000	86	0.08000000	0.02000000
6	2017	FU2021	HISTORICAL RE-VIEW	0.41757863	86	0.07040892	0.01670275

```
knitr::kable(k.sum2017[, c(1:2, 16, 8:12)])
```

	Year	Ground	method	ci	area	abund	upper	lower
5	2017	FU2021	ORIGI-NAL COUNTS	347.00000	9978.0000	4428.0000	4775.1552	4080.8448
6	2017	FU2021	HIS-TORI-CAL RE-VIEW	316.34849	9978.3286	4250.4293	4566.7778	3934.0808

```
knitr::kable(k.sum2017[, c(1:2, 16, 13:15)])
```

	Year	Ground	method	CViid	meanGeo	CVgeo
5	2017	FU2021	ORIGINAL COUNTS	0.16000000	0.44000000	0.04000000
6	2017	FU2021	HISTORICAL REVIEW	0.14663521	0.42596606	0.03797317

```
write.csv(k.sum, "Labadie_Summary_ADG_2017_Historical_review.csv")
```

5.12 Final check: cross validation plot

```
data.db <- xvalid(db.c1, model = vg.fit, uniquenei)
hist(db.extract(data.db, "Xvalid.AdjustedBurrowDensity.esterr"), ncla
ss = 30,
    main = "CrossValidation", xlab = "Cross validation error", col =
"blue")
```

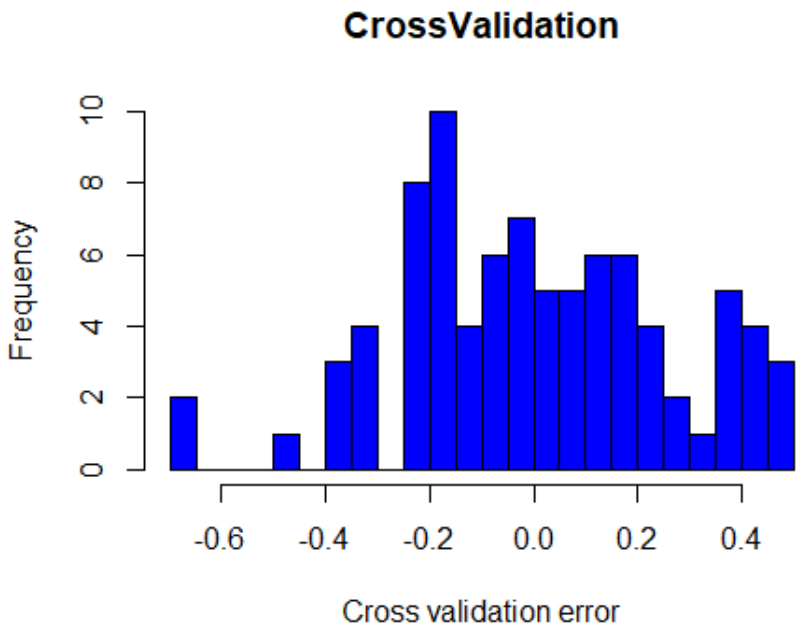


Figure 24: 2017 FU20-21 UWTV cross validation plot

6 Abundance among years including Historical Review for 2016 and 2017

```
k.sum.2016 <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC
SEA/",
    "Historical review Labadie 2016/Kriging/Labadie_Sum-
mary_ADG_2016_Historical_review.csv"))

k.sum.2017 <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC
SEA/",
    "Historical review Labadie 2017/Kriging/Labadie_Sum-
mary_ADG_2017_Historical_review.csv"))

k.sum.2018 <- read.csv(paste0("N:/Surveys/UWTV SURVEYS FU2022 CELTIC
SEA/",
    "2018 Labadie/Kriging/Labadie_Summary_ADG_2018.csv"))
k.sum.2018$method <- "ORIGINAL COUNTS"

abundance <- rbind(k.sum.2018, subset(k.sum.2016, method == "HISTORI-
CAL REVIEW"),
    subset(k.sum.2017, method == "HISTORICAL REVIEW"))
abundance <- abundance[, -1]
ggplot(abundance, aes(x = Year, y = abund, col = method)) + geom_er-
rorbar(aes(ymax = upper,
    ymin = lower, width = 0.25), linetype = 1) + geom_line(aes(line-
type = method)) +
    geom_point(size = 1) + coord_cartesian(ylim = c(0, 5000), xlim =
c(2013,
    2018)) + scale_x_continuous(breaks = seq(2013, 2018)) +
scale_linetype_manual(values = c(0,
    1)) + scale_colour_manual(values = c("#00BFC4", "#F8766D")) +
labs(x = "Year",
    y = "Abundance (millions)") + theme_bw() + theme(legend.position
= "bottom",
    panel.grid.major = element_blank(), panel.grid.minor = ele-
ment_blank())
```

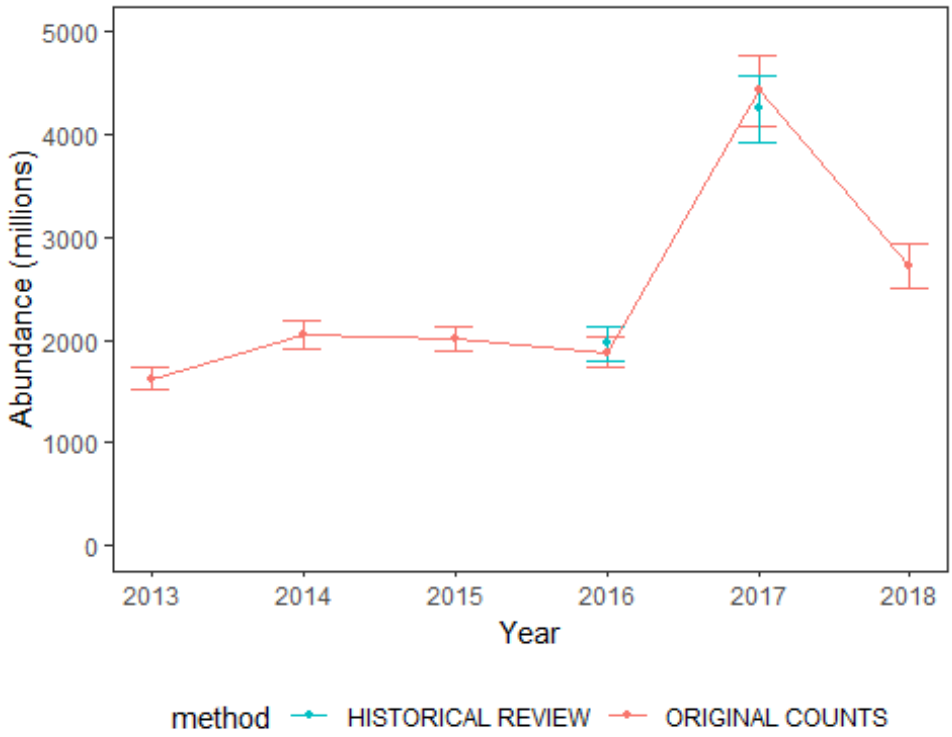


Figure 25: Original survey abundance estimates among years (in red), and Historical Review estimates for 2016 and 2017 (in blue)

Annex 8: Descriptions and manuals for Nephrops trawl surveys

Annex 8.1 Agri-Food and Biosciences Institute

Standard Operating Procedure

SOP Code:	FAEB (Branch)	MARFISH (Unit/Group)	006 (SOP No.)	V6 (Version)
Location (e.g. Newforge Lane):	Newforge Lane			
Author:	Marine Fisheries Section, FAEB			
Title:	Sampling at sea aboard RV *Corystes*: *Nephrops*			
Purpose: (please specify: analyse / measure / test / operate a method / equipment etc)	This procedure details the operations to be carried out in order to ensure that the following is conducted in a consistent manner: Sampling at sea aboard RV *Corystes*: *Nephrops*			
Date of creation /amendment:	01/03/2014			

It is the project leader's responsibility to ensure that the appropriate SOP is specified for scientific work and that the SOP and training are provided to staff conducting the work. It is the responsibility of the operator to follow the method, to record which SOP is used and any deviation from the written SOP.

- **Procedure**

Guidance:

- *Standard operating procedures may be in numbered point format, with or without subheadings, or in a different format as appropriate to the work.*
- *Any other documents referred to must be clearly cross-referenced.*
- *If it is necessary to amend the SOP, a new version must be created and copied to all who use it. Old versions must be withdrawn and archived and dates of amendments recorded.*

Signed:	(author)	(date)
	(laboratory manager)	(date)
	(unit manager or project leader)	(date)

CONTENTS

1. **Scope**

Nephrops research cruise aboard the AFBI research vessel RV *Corystes* is performed every year in the period July-August using a beam trawl similar to that used in the commercial fishery. Trawling during these cruises is in regions sampled in previous trips and data are added to a time-series database. The general objectives of these studies are.

i) To study spatial variability of population structure and abundance of *Nephrops* and bycatch species.

ii) To obtain information on temporal trends of population structure of *Nephrops*.

iii) To study female maturity in *Nephrops*.

Each sampled station comprises a 3-mile trawling lane. Towing speed across the ground varies with tide and weather but is 3 knots on average. As far as is possible, the same areas are trawled in each survey.

2. **Field of application**

The data collected in the surveys are used in studies of fish and shellfish biology, ecology and population dynamics. The surveys provide important information supporting the scientific assessment and management of *Nephrops* in FU15; in addition, they provide information on bycatch species from the Irish Sea.

3. **References**

Risk assessment documents (and relevant manual handling checklists):

MARFISHRA01: Collecting and processing samples of fish and shellfish

MARFISHRA06: Living and Working aboard a research vessel

4. **Principle**

The trawl catches are sorted to species level; *Nephrops* carapace length is measured to the nearest millimetres below, using vernier calipers. The maturity stage of female *Nephrops* catch are classified according to an arbitrary scale consisting of 5 different stages:

Stage I - Immature; ovaries as thin white threads

Stage II - Ovaries thicker than in 'I' with a tinge of pale green colour.

Stage III - Ovaries larger than 'II' and dark green in colour.

Stage IV - Ovaries much larger than 'III' and clearly visible through the carapace. Dark green/black colour.

Stage V - Ovaries pale green with dark green specks. This stage is uncommon in the NW Irish sea and represents re-absorption of ovarian material

Berried - Ovigerous females with eggs attached to the pleopods.

Length measurements are also carried out on each fish bycatch species. Because of the large size of the catches and the many species and size classes of fish present, it is often not possible to sort all the catch. Also, it is only possible to measure a fraction of the catch sorted. Hence, samples must always be taken in such a way that they are fully representative of the catch as a whole. This is achieved by splitting the catch of each bycatch species into rough size categories of fish (e.g. big, medium and small) followed by random subsampling, as described in sections 7-10.

5. **Reagents**

Some samples, e.g. fish ovaries and specimens for museum collections, are preserved in buffered 4% formaldehyde solution.

SOP MARFISH001 Preparation of 4% Buffered Formaldehyde solution must be followed when preparing 4% formaldehyde solution from 40% W/W formaldehyde solution.

6. **Equipment**

The Nephrops Survey equipment inventory list is available in P:\AFESD\FAEB\Marine Fisheries\Otolith\SOP1\Nephrops_Equip_Checklist

Tick off each item at the lab and again when unpacking. Ensure that a key of Nephrops maturity stages is on board. Ensure the equipment is loaded and checked sufficiently in advance of sailing to allow missing items to be replaced.

The list should be checked and signed for by the person responsible for loading the ship, and present it to the SIC prior to the vessel leaving port.

P:\AFESD\FAEB\Marine Fisheries\Otolith\SOP1\MARFISHFM DataSheets

MARFISHFM15

MARFISHFM16

MARFISHFM17

MARFISHFM08

MARFISHFM09

MARFISHFM10

MARFISHFM11

MARFISHFM12

MARFISHFM28

7. **Sampling**

See (8) below.

8. **Operational procedure**

Recording the species composition

The catch is emptied into the fish hopper aft off the wet lab. The hopper holds approx. 1 tonne of fish. Most catches in the Irish Sea are between 100 and 500 kg i.e. 3 - 15 baskets of 30 kg each. The entire catch can generally be sorted to species if it is about 100 kg or less; larger catches require a stratified sampling scheme.

The SIC is directing the operations for sorting the catch.

- Remove from the hopper (directly or at the exit chute) all large and /or fish, large jelly fish and rubbish. Count the jelly fish before they are thrown overboard and put the large fish into baskets.
- Fill equally-sized baskets with the remaining smaller fish.

Take a random sample of baskets from the catch of smaller fish into the lab for sorting. Count any unsorted baskets before they are discarded (record the baskets on a waterproof pad as they are dumped). It is important that baskets are selected in a sensible manner for sorting, allowing for variations in the species and size composition in different parts of the hopper. In particular, there may be a degree of sorting by size with larger fish or flatfish on the surface of the catch and smaller fish at the hopper exit chute.

- In the lab, empty each basket onto the sorting bench and sort out all *Nephrops*, "medium" sized whiting and other species that can be quickly picked out. *Nephrops* are sorted into males and females by examining the appendix masculina of each animal. Length measurements are also carried out on each bycatch species. The maturity stage of *Nephrops* catch are classified according to

an arbitrary scale consisting of 5 different stages. Samples of selected fish species are taken for biological analysis.

- Mix the remaining quantity of small fish from each basket well and ta*ke sever*al subsamples from different parts of the bench. Store the sub sample in a *marked* fish basket(s). Take as large a subsample as can be sorted in the time available between stations, bearing in mind the time required for subsequent biological analyses.
- If *the amo*unt of small fish is small enough, all can be sorted. Ensure that the unsorted mixture of small fish is weighed before it is discarded.

The sorted catch will now (usually) contain:

- Male and female *Nephrops*.

- Fish picked out from the catch while on the deck (e.g. large fish), and representing the entire catch of that species or size category;

- "medium-sized" fish of each species sorted in the lab, and which will only represent the entire catch of the species if all the baskets in the catch are brought into the lab for sorting;

- samples of "small" fish which may have been obtained either by sorting all of the catch remaining after the "medium-sized" fish have been taken out, or by taking small subsamples from each basket and sorting these to species;

- a remaining unsorted catch of small fish which will only be present if the small-fish mix was subsampled.

If the total catch of a given species is now sorted into two or more samples of fish of different size-ranges, these are referred to as "size categories". The categories are given a number as follows:

0:	Catch not sorted into size categories
1:	Large fish category
2:	Medium fish category
3:	Small fish category
4:	Even smaller fish category.

The weights in each category of each species are recorded, as well as the weight of any unsorted catch.

Recording length-frequencies

The next step is to record the size composition of the *Nephrops* and fish in each category as accurately as possible. The carapace lengths of male and female *Nephrops* are measured separately to the nearest millimetre below, using vernier calipers. Greatest accuracy is required for commercial whitefish species for which indices of abundance of different age-classes are required for scientific stock assessments (cod, whiting, haddock, herring). For those species, take a sufficient number of fish at random from each category such that there are approximately 50 fish in the modal length class of the measured fish.

Where there are several modes in the length frequency it may only be feasible to measure to about 30 in a mode. If there are several baskets of fish, take a subsample from each basket.

Sample-sizes for non-commercial species such as poor cod and sprat may be smaller, e.g. a total of 50-100 fish depending on the spread of length classes.

Record the weight of fish in the length frequency and enter it onto the length-frequency form together with all other relevant details, particularly the category number.

All fish are measured to the nearest cm below (pelagic fish, such as herring, sprat, mackerel, are measured to the 0.5 cm below), and are measured from the tip of the nose to the tip of the tail (total length). Record the fish in groups of five, either as four vertical strokes and the fifth as a diagonal through these, or as a box with the fifth fish as a diagonal.

Recording biological data

The maturity of female *Nephrops* is assessed according to an arbitrary scale ranging from 1 through to 5 based upon the size and colour of the ovary viewed through a dorsal break made in the integument just posterior to the carapace.

Occasionally biological sampling of bycatch species occurs as described in the SOP for sampling demersal fish (MARFISH003)

9. **Expression of results**

All weights are recorded as kg except on the biological sample forms MARFISHFM11 and 12 where the weight of individual fish is recorded in g. *Nephrops* carapace lengths (from the eye socket to the posterior mid dorsal point of the carapace) are recorded in mm and fish lengths are in cm. For length-frequencies, data must be recorded to the nearest mm below for *Nephrops* and to the nearest cm below for fish (0.5 cm below for small pelagic). For biological samples, data must be recorded to the nearest mm.

10. **Quality assurance**

Balances are verified before use and values recorded on form MARFISHFM28. See SOP MARFISH033.

Do not discard any fish until you are sure that the weights and lengths have been recorded.

Ensure that the sample forms are fully and properly completed before giving them to the computer operator. In particular, ensure that the forms are neatly and legibly filled in, and that any computations are clearly documented. The accuracy of raising calculations can be checked against the number of baskets of fish known to have been in the catch: a basket of fish weighs about 30 kg, whereas a basket of prawns is about 20 kg.

11. **Reporting of results**

Recording forms for details of trawl deployment

These are filled in by the fishing skipper on form MARFISHFM15 during each trawl. The positions, times, depths, ships heading and log reading are recorded at the commencement and completion of the tow (from the time the net reaches the seabed to the

time it lifts off again). Times are in GMT. Average sea temperature at surface and at the net are recorded, together with wind direction and strength (mph). The distance towed across the ground is accurately recorded. ScanMar data are printed out or recorded manually. Average headline height is recorded.

Recording forms for catch composition and length

The data are recorded initially on forms which are designed to facilitate entry of the data on computer. Follow the instructions printed on the forms. You need to become familiar with the species codes and the WMC codes:

Large fish removed from the pond

Where all the individuals of a species are taken out of the total catch at the pond and are not broken down into size categories, enter the weight of the catch of that species directly into the "category 0" column under "total catch" on the species composition log sheet. If the fish have been categorized by size, enter the catch weights under the appropriate size-category.

Baskets taken to lab for sorting

If only part of the catch is sorted, enter the weight of each species (by size category) in the sorted baskets into the appropriate column under "mass in sorted fraction" on the log sheet. Calculate the raising factor: i.e. ratio of total baskets to sorted baskets. Multiply the mass of each species in the sorted fraction by the raising factor and enter the resultant figures under "total catch" in the appropriate size category.

Where the baskets have been further subsampled to determine the species composition of a mixture of small fish, write the weights in this subsample clearly on the back of the log sheet together with the weight of the unsorted mix of small fish. Then raise the weights of the different species and size categories in the subsample up to the total amount of the small-fish mixture in the baskets taken into the lab for sorting. Enter these raised weights in the appropriate columns under "mass in sorted fraction", with an asterisk to indicate that they represent raised subsample weights. All calculations must be clearly laid out on the back of the log sheet.

Data entry on computer

All data collected each day should be entered on the same day to avoid backlog building up.

12. **Safety**

Safety gear comprising of a flotation aid, hard hat and safety shoes/boots with steel toecaps must be worn while working on the deck.

Do not work on deck while trawling is being carried out.

If opening or closing doors on the vessel, ensure they are properly and securely fastened.

Ensure that equipment is properly secured in rough weather.

12.1 Protective gloves and non-slip safety shoes/boots with steel toe-caps must be worn. Wear waterproof bib & brace trousers or a boiler suit/laboratory coat and a waterproof apron while working at hopper and in the wet lab.

Think before lifting heavy and/or awkward objects. Ensure that you comply with the Manual Handling Operations Regulations (Northern Ireland) 1992. Never be afraid or too embarrassed to ask for help with a 'lift'. The Health and Safety at work legislation requires everyone to have a duty of care both to themselves and to others.

Always split the load in smaller portions when possible before handling and lifting.

Always try to establish a comfortable measuring platform to avoid kneeling and stooping.

Take adequate pauses to rest muscles, ensure the measuring board is in a suitable stable position that avoids the need for twisting. Rest individual fish on the measuring board, so that the weight of each fish is supported by the handler for the minimum length of time.

The lifting of all fish baskets MUST be shared by two persons.

N.B. Correct use of Protective Gloves

Protective gloves in various thickness are provided for your protection. All staff must wear protective gloves when handling or sorting fish/shellfish and where appropriate when carrying out other tasks.

The correct gloves to wear are those which provide appropriate protection from the suspected risk (claws, teeth, spines, fish bones, toxins and electric shock) and which do not restrict hand movements to an unnecessary degree.

In addition, the degree of operator experience and the liveliness of fish and shellfish in the sample will also determine the choice of gloves to be worn. If you are unsure of any procedure or the degree of protection to be used, consult your line manager **before** beginning work.

Annex 8.2 Description of the trawling activity linked to UWTV surveys carried out in the Pomo Pits area, central Adriatic Sea (part of GSA17) by CNR-IRBIM of Ancona (Italy) in collaboration with IOF of Split (Croatia).

Pages extracted from:

Martinelli M., Belardinelli A., Guicciardi S., Penna P., Domenichetti F., Croci C., Angelini S., Medvesek D.,

Froglia C., Scarpini P., Micucci D., Isajlović I., Vrgoč N., Santojanni A. 2017. Report of the Underwater

Television survey (UWTV) activities in 2016 in Central Adriatic Sea. Document presented at the 18th

Meeting of the AdriaMed Coordination Committee (Tirana, Albania, 16-17 February 2017). FAO AdriaMed: CC/18/info 12.

Trawl hauls data

During the UWTV survey in the Adriatic Sea, trawl hauls are usually carried out at sunrise and sunset (peaks of emergence from burrows of *Nephrops norvegicus*; Froglia and Gramitto, 1986) in order to obtain supplementary data such as indications of the size composition of the *Nephrops* population in the area. Furthermore, catches of hake and other associated species are recorded during the survey. The gear used is an experimental trawlnet built on the model of a Scottish "16 fathom prawn trawl" net with mesh size of 22 mm in the body and 12 mm in the codend. The net is equipped with SCANMAR sensors in order to allow to follow its behavior during the haul and especially to define the average horizontal opening of its mouth. The hauls generally have a duration of 1 hour (in fishing phase). Through a GPS system, the position of the ship is recorded minute by minute; the position of the vessel is then used as a proxy of the net location on the seabed for the calculation of the track length. For each haul, the total weigh and the catch composition are noted down (if it is necessary a significant subsample is analysed and then the total catch is reconstructed proportionally by means of a raising factor). All species of commercial or ecological interest are sorted (weight and number of individuals are recorded) and, when possible, also the various types of discards (e.g.. organic, wood, glass, plastic etc...).

Nephrops norvegicus, Merluccius merluccius, Parapenaeus longirostris, and *Micromesistius potassou* are considered target species, thus their length frequency distributions are recorded. The two crustaceans are also divided by sex/category (male, female or juveniles).

Also the catch data and the GPS tracks are collected in a database built with the Manifold® System Release 8 software, that allows the calculation of the swept-area (multiplying the path covered in meters by the average opening of the net mouth) and thus that of the catch per unit of effort (CPUE, kg/km^2) of each haul and each species and by stratum.

As an example, in this document are reported some preliminary data and calculations based on the original stratified random design (the additional hauls carried out for MIPAAF were excluded). In the processing for stratum, strictly the hauls carried out at sunrise and sunset were considered in order to obtain comparable data, not affected by variations in vulnerability due to the circadian rhythms of the species. The calculated CPUE (kg/km^2) and indices of biomass (ind/km^2) per species and per stratum are reported in Annex II together with the number of hauls considered, the swept-area, the total catch and the number of individuals per stratum.

In Figure 9 are shown length frequency distributions (in percentage and divided by sex) of *Nephrops norvegicus* derived from the hauls carried out during the I-UWTV Survey 2016, according to the 4 strata described in Figure 3, see also Table 2. The same is shown in Figure 10 for *Parapenaeus longirostris;* sometimes juvenile rose shrimps were too small to be sexed on board, thus samples were taken to the lab and the derived sex ratio for size class were applied to assign individuals to male and female categories. Figures 11 and 12 shows respectively the length frequency distributions in percentage

of *Merluccius merluccius* and *Micromesistius potassou* for the same strata; that of *M. potassou* is not very reliable due to the small number of measured animals (less than 300 in total).

Table 2: Results obtained from the I-UWTV survey 2016 for *Nephrops norvegicus* according to the original stratified random design.

Year	Stratum	n. of valid stations	Surface viewed (m²)	Surface of the stratum (km²)	Edge Effect %	Density of burrows (n·m⁻²)	s.d. (n·m⁻²)	n. of trawl hauls	n. of *Nephrops* measured	Average carapace length (cm)
2016	DC	3	656.307	448.920	24.563	0.930	0.578	2	322	24.792
	DI	19	4723.200	1703.030	19.731	0.994	0.419	5	1280	26.351
	SC	3	693.243	993.170	20.807	0.912	0.129	1	233	22.648
	SI	13	2965.505	1699.520	19.985	1.121	0.353	5	1491	25.088

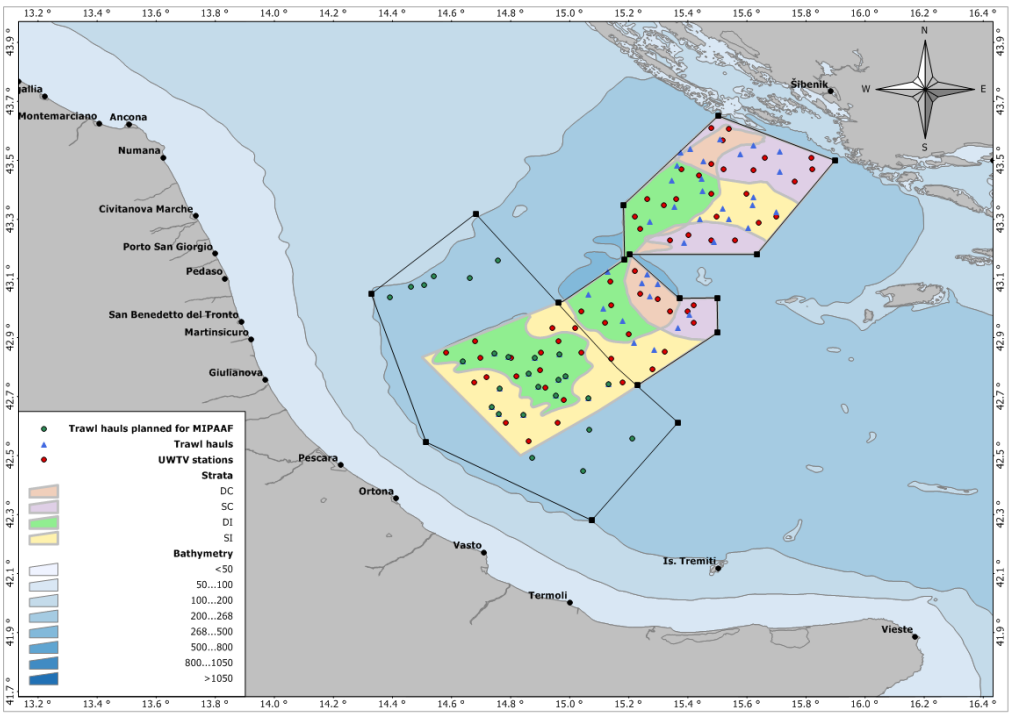


Figure 3. Red dots: UWTV stations; blue triangles: trawl hauls; green dots: trawl hauls planned for CNR/MIPAAF agreement; colored polygons: strata of the original stratified random sampling design (DC: deep Croatian territorial waters over 200 m depth, DI: deep international waters over 200 m depth, SC: shallow Croatian territorial waters less than 200 m, SI: shallow international waters less than 200 m).

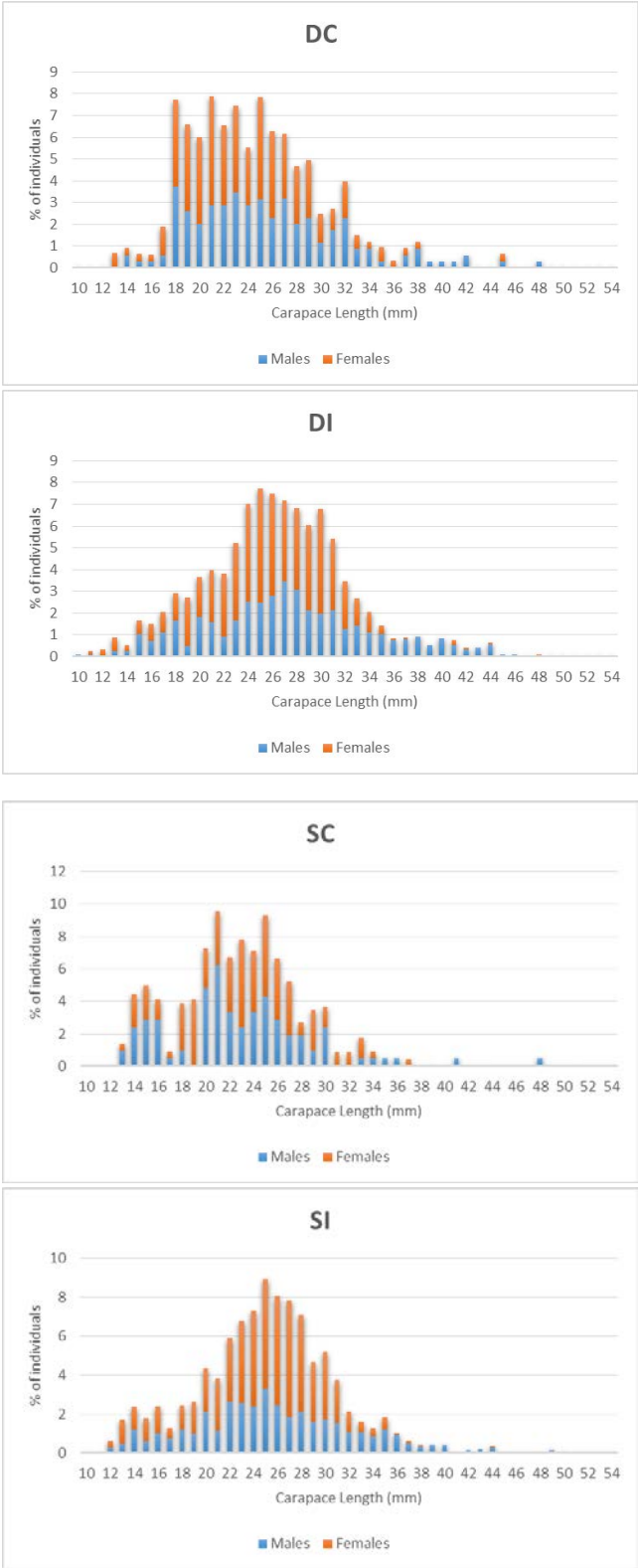


Figure 9. Length frequency distributions (%) of *Nephrops norvegicus* derived from the hauls carried out during the I-UWTV Survey 2016, according to the four strata described in Figure 3.

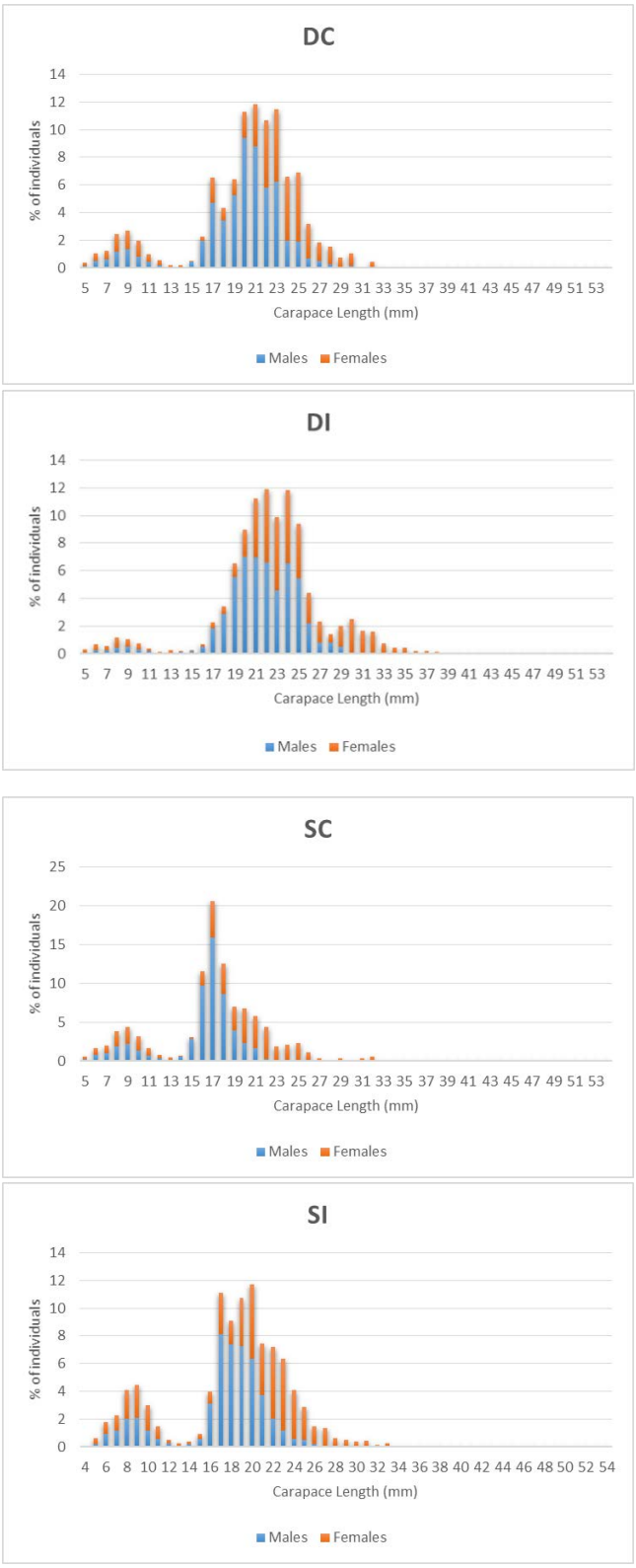


Figure 10. Length frequency distributions (%) of *Parapenaeus longirostris* derived from the hauls carried out during the I-UWTV Survey 2016, according to the four strata described in Figure 3.

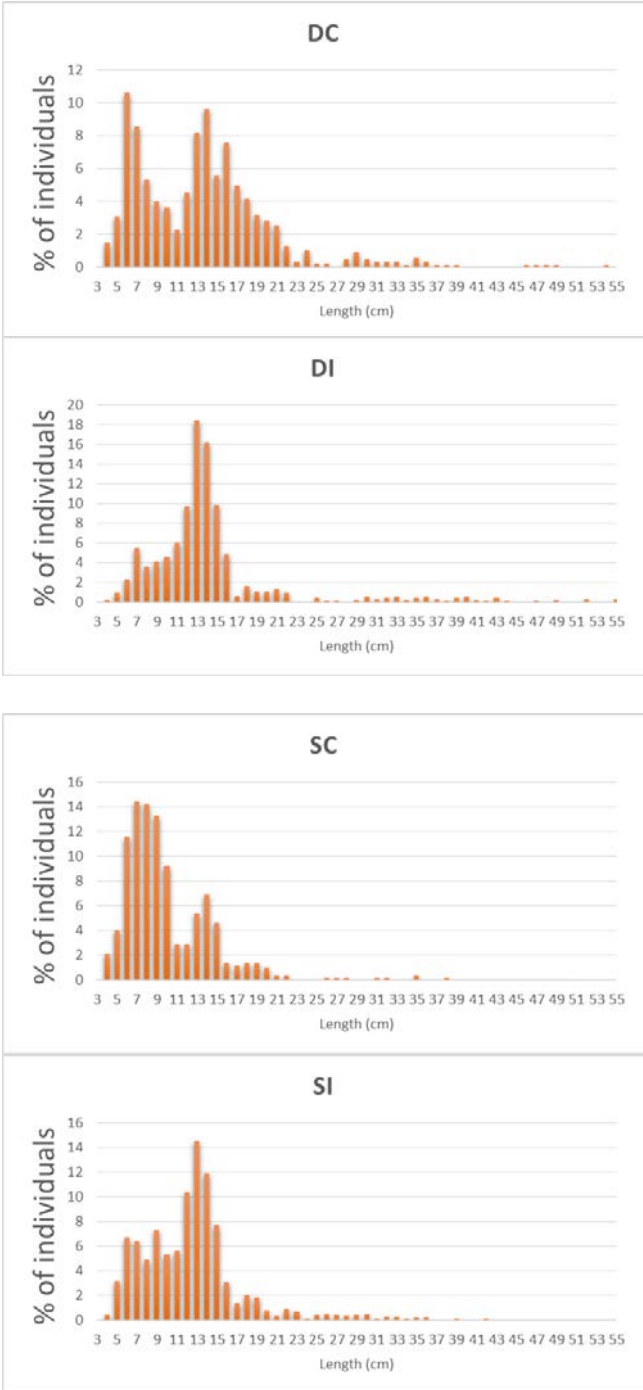


Figure 11. Length frequency distributions (%) of *Merluccius merluccius* derived from the hauls carried out during the I-UWTV Survey 2016, according to the four strata described in Figure 3.

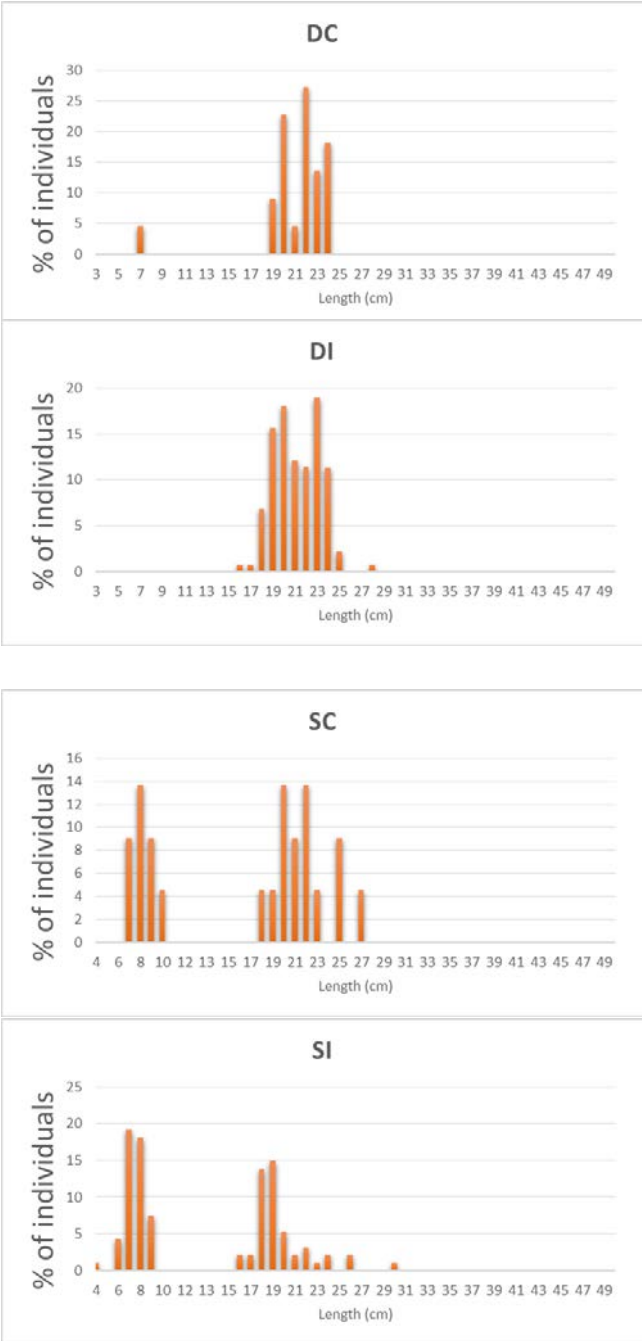


Figure 12. Length frequency distributions (%) of *Micromesistius potassou* derived from the hauls carried out during the I-UWTV Survey 2016, according to the four strata described in Figure 3.

Annex 8.3: FUs 28 and 29 (Southwest and South Portugal) *Nephrops* offshore Survey (NepS)

1 Introduction

The Norway lobster, *Nephrops norvegicus* (herein after referred as *Nephrops*), is distributed along the continental slope in these FUs, at depths ranging from 200 to 800 m. Its distribution is limited to muddy sediments, with a silt and clay content of between 10–100% where *Nephrops* excavates its burrows, this meaning that the distribution of suitable sediment defines the species spatial distribution.

In FUs 28 and 29, *Nephrops* is caught in a mixed trawl fishery directed at crustacean species (Figure 1.4), which the most important is the rose shrimp *Parapenaeus longirostris*. Although the rose shrimp has a shallower distribution, the fishing grounds for these species overlap in the depth range of 200 - 400 m. The distribution of *Nephrops* extends further to deeper grounds down to 800 m.

Other target species are *Aristeus antennatus* (blue and red shrimp) and *Aristaeomorpha foliacea* (giant red shrimp), in areas deeper than 400 m and *Aristaeopsis edwardsiana* (scarlet shrimp), in very deep grounds (600 - 1000 m).

The fish bycatch species include hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), blackbelly rosefish (*Helicolenus dactylopterus*), greater forkbeard (*Phycis blennoides*) and catsharks (*Scyliorhinus canicula* and *Galeus melastomus*).

The Portuguese crustacean surveys have been conducted since 1981, in different areas and seasons. The areas surveyed in each cruise varied, extending from 36° 59′ N northwards to 41° 51′ N and 7° 51′ W to 9° 57′ W and covering depths from 150 down to 750 m off the continental shelf. Since 1997, the crustacean survey has been conducted once a year, during the second quarter, covering the whole area of FUs 28 and 29.

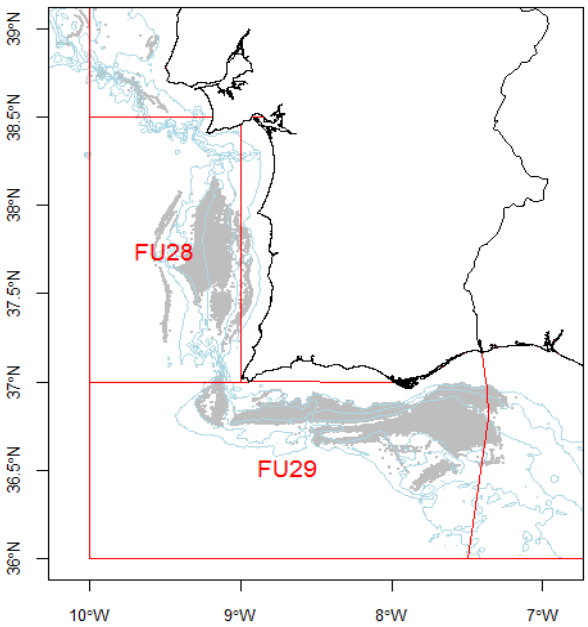


Figure 1. ***Nephrops*** **fishing grounds in FU 28 and 29, based on VMS data (grey area).**

2 Objectives

Main objectives:

- To estimate the relative abundance of *Nephrops* and deep-water rose shrimp for use in the assessment and advice process, with a CV (relative standard error) of less than 20%.
- To study their geographical distribution in space and time.
- To collect data for the determination of biological parameters (sex-ratio, length-weight relationships, maturity, growth), meet DCF sampling requirements and provide LFD time-series.

Secondary objectives:

- To monitor the distribution and relative abundance of the accompanying fish and invertebrate species.
- To collect data for the determination of biological parameters for selected fish species.
- To collect data for biodiversity studies and information on marine litter distribution to comply with MSFD requirements.
- To collect hydrographic and environmental parameters (e.g. Temperature, salinity, turbidity, oxygen, etc.)
- To collect sediment data to improve the definition of *Nephrops* habitat.

3 Survey sampling design

The Portuguese crustacean surveys have been conducted since 1981, in different areas and seasons. The surveys were carried out with the research vessels «Mestre Costeiro» and «Noruega» and the areas surveyed in each cruise varied, extending from 36° 59′ N northwards to 41° 51′ N and 7° 51′ W to 9° 57′ W and covering depths from 150 down to 750 m off the Portuguese mainland coast. Prior to 1997, the surveys were mainly exploratory with no clearly defined survey design.

Since 1997, the crustacean survey has been conducted once a year, covering the south-west and south coasts of Portugal, which correspond to the Functional Units 28 and 29 of ICES Subarea 9a, respectively.

In 1997, the sampling design was adapted from the bottom trawl surveys (stratified random sampling) and formed the basis for the survey data collection in the period 1997-2004. The southwest and south coasts of Portugal were divided in sectors and each sector split in depth strata. The number of trawling stations in each stratum was dependent on *Nephrops* and rose shrimp abundance variance, with a minimum of 2 stations per stratum. The average number of stations in the period was 60. These surveys were carried out in May-July and had a total duration of 20 days.

Due to the small number of samples in some strata and to the random selection of the positions, this design does not allow the use of geo-statistical methods. For this purpose, a regular grid composed by 77 rectangles is used since 2005, with one station within each rectangle. Each rectangle has 6.6 minutes of latitude x 5.5 minutes of longitude for the SW coast and vice-versa for the south coast, corresponding approx. to 33 nm2. The abundance observed at a particular point within the rectangle will reflect the relative abundance of the resource at that geographical area and it is assigned to the centre of the rectangle.

The total duration of the survey was the same (20 days) and the haul duration had to be reduced from 60 to 30 minutes in order to cover all the rectangles of the grid.The stations could be grouped *a posteriori* in the previously used strata and the results compared with the former surveys.

The grid has been updated to include areas where fishing is known to occur and to exclude others where the target species do not occur or non-trawlable areas, based on the definition of the fishing grounds through VMS fishing records and it currently includes 78 rectangles, with 21 in FU 28 and 57 in FU 29. The areas deeper than 750 m,

where the scarlet shrimp occurs in FU 28, are not covered (Figure 2). Table 2 presents the summary statistics for the *Nephrops* trawl surveys for the period 2005-2018, after the change to the grid sampling design.

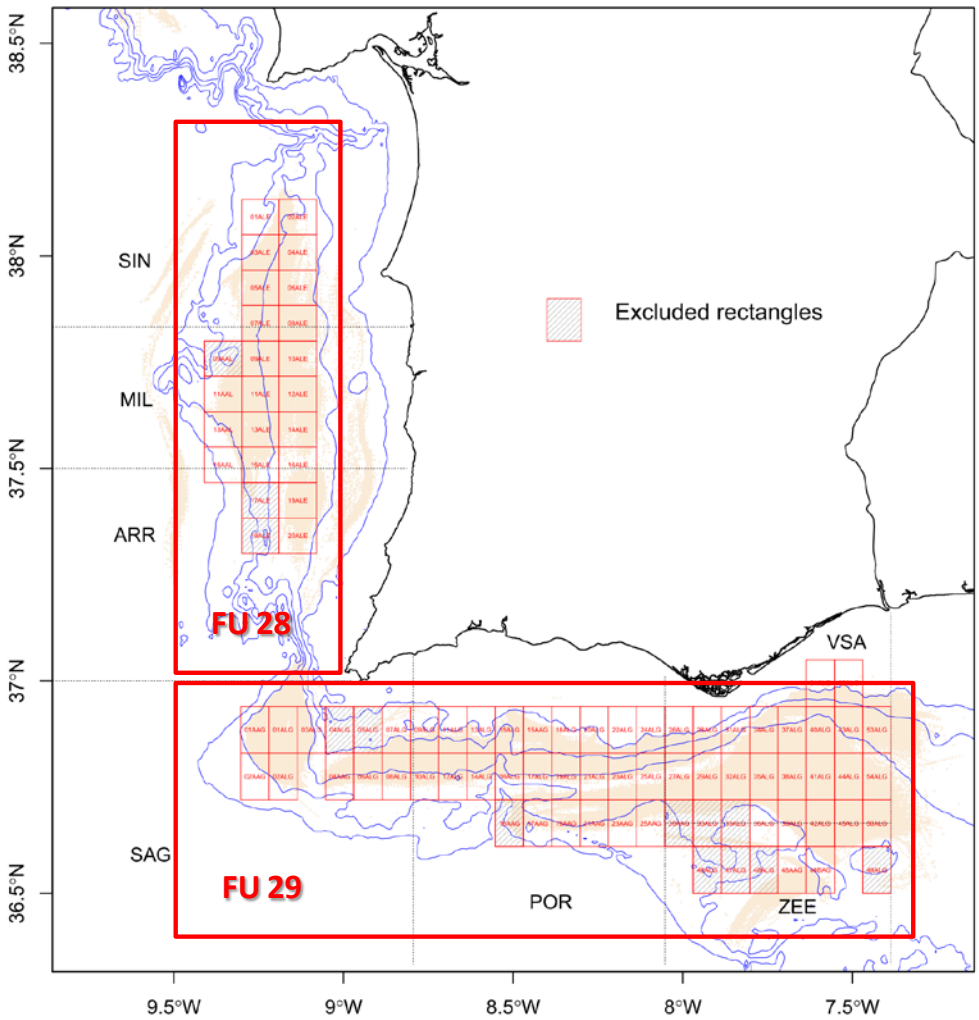


Figure 2. Survey grid in FUs 28 and 29 overlaying the crustacean fishing grounds represented by VMS fishing records. The grey-dashed rectangles were removed from the grid survey. The sectors used in the previous stratified design are also shown, delimited by dotted lines and labeled.

Table 2. Summary statistics for *Nephrops* surveys giving recent average numbers of stations (2005 - 2017), ground area, station density, design and relative standard error (CV).

Name	FU	Nb Stations (average 2005-2018)	Ground (km^2)	Stations/ 1000 km^2	Design	CV (%)
Southwest Portugal	28	20	1,925	~11	Grid (2005-2018)	19-28
South Portugal	29	51	4,502	~11		
Total	28-29	71	6,426	~11		

4 Observation methodologies

4.1 Protocol for sampling gear and instrumentation

The surveys are carried with the RV "Noruega", which is a stern trawler of 47.5 m length, 1500 horse power and 495 GRT. The fishing gear used is a shrimp trawl (type FGAV020) with a 20 mm codend mesh size. The main characteristic of this gear is the groundrope with synthetic wrapped wire core and chain. The vertical opening is 1.5 – 2.0 m and the mean horizontal opening between doors is 60 m. The polyvalent trawl doors used are rectangular (2.7 m x 1.58 m) with an area of 3.75 m2 and weighting 650 Kg. Figure 3 shows the gear design.

The following table summarizes the characteristics of the research vessel, gear and haul operation in *Nephrops* Trawl surveys in FU 28-29

Characteristics of the gear	**FU 28 - 29**
Research Institute	IPMA
Research Vessel	Noruega
Type	Stern Trawler
GRT	495
KW	1100
Overall Length (m)	47.5
Gear Type	Shrimp trawl FGAV020
Codend mesh size (mm)	20
Depth range (m)	150-750
Trawling speed (knots)	3
Haul duration (minutes)	30
Doors weight (kg)	650
Doors surface (m2)	3.75
Floats in Headline/winglines	9
Average vertical opening (m)	1.5-2.0
Average doors spread (m)	60
Average horizontal opening (m)	30
Groundrope	Synthetic wrapped wire core + chain

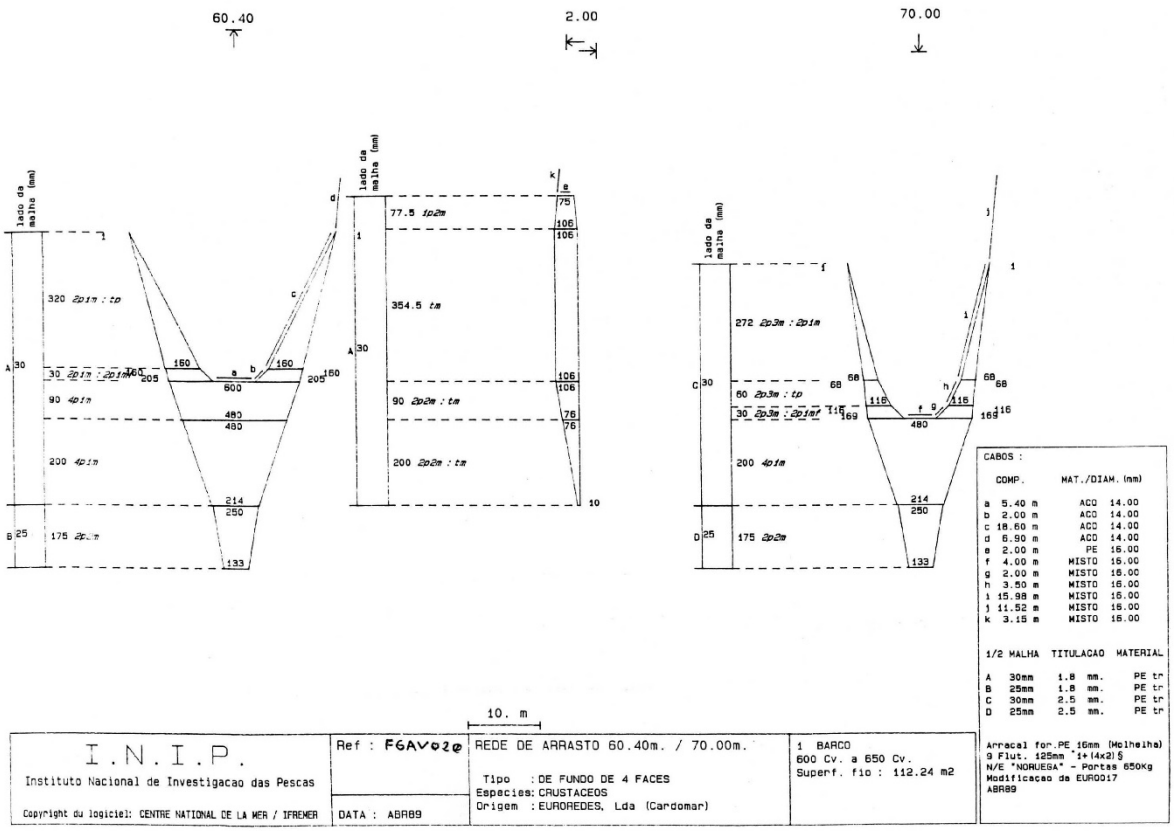


Figure 3. Scheme of the shrimp trawl gear used in Portuguese crustacean surveys.

Start time of the haul is defined as the moment when the vertical net-opening and door spread are stable. Stop time is defined as the start of pull back. The haul duration is 30 minutes. Hauls with duration lower than 15 minutes are not considered valid. Hauls are carried during daylight at a mean speed of 3.0 knots. SCANMAR sensors to monitor the trawlnet parameters (wings/doors spread, horizontal and vertical openings) are used in FU 28 and 29 on an irregular basis.

UWTV experiments with a net camera

In 2005 and 2007, some experiments to collect UWTV images from the *Nephrops* fishing grounds were made with a camera hanged from the trawl headline. A SeaCorder (composed of a MD4000 high resolution colour camera, a MP4 video recorder and a 30 Gb hard drive) was hanged at the central point of the headline, pointing forward onto the sea floor with an angle of 45 degrees, approximately. In 2008, the images collected from 9 stations in FU 28 with the same procedure looked very promising. In 2009 survey, a two-beam laser pointer was attached to the camera and UWTV images were recorded from 58 of the 65 stations. The video images were recorded in AVI format for the whole duration of each haul. These files were edited and divided in smaller files for better observation. The trawling speed and the turbidity were the main problems affecting the clarity of the image and the high variation of the height of the camera to the ground resulted in a variable field of view. It was concluded that this method could not be used for abundance estimation and it was abandoned.

4.2 Protocol for collecting biological samples

It is recommended that the catch from all valid hauls be sorted fully were practicable. Wherever possible, the entire catch is sorted, with fish and shellfish species identified to the lowest taxonomic level possible. In the case of a large catch of one dominant species, or larger catches in which a small number of species are sufficiently abundant, these can be subsampled, appropriately, with the rest of the catch fully examined for 'rare' species and any exceptionally small or large individuals of the species that are subsampled.

Length distributions are recorded for all commercial crustaceans, fish and other species caught.

Length is measured to the:

- 1 mm below for commercial crustaceans (cephalothorax or carapace length/width and total length)
- 1 mm below for commercial cephalopods (mantle length)
- 0.5 cm below for small pelagic fish (total length)
- 1 cm below for all other fish species (total length).

Biological data (i.e. sex, length, weight, maturity stage) are collected. Hard structures (otoliths and

illicia) are collected for some of fish species.

5 Caveats

Nephrops inhabits the muddy bottom of continental shelves and slopes in the Atlantic and Mediterranean Europe, where it digs burrows of complex architecture. The burrowing lifestyle of *Nephrops* conditions its behaviour and physiology (Aguzzi and Sardà, 2007). Animals mainly emerge to feed but also, most social interactions, such as mating and moulting, occur outside the burrow. Animals can be captured by trawl hauls only while they are out of their burrows and catch patterns can be used as a proxy of animal emergence rhythms. Trawling surveys repeated continuously during 24 hrs on the Atlantic upper (< 30 m) and lower shelf (50-200 m) showed that peaks in captures took place at different times of day for increasing depths. On the upper shelf, peaks occurred at night, while they were crepuscular (i.e. at sunset and sunrise) on the lower shelf. Catches at 100 m were still crepuscular, but these became fully diurnal at 400 m (Aguzzi and Sardà, 2007).

The swept-area method using trawling is a direct and simple method for abundance estimation because catchability relies on individuals actively emerging from their burrows. The proportion of the biomass that is taken by the trawl depends on the depth (related to light penetration which conditions the emergence pattern), and on the catchability of the gear. Therefore, the trawl survey does not provide an estimate of total absolute biomass but an index of relative biomass/abundance.

A good estimation of the population density based on catchability data can be produced only when surveys are conducted in identical circumstances with special reference to the time of the day and the season. Biases in the estimation of population demographic size are likely to occur if the timing of sampling is not properly taken into account. In spring and summer, catches usually increase because animals spend more time out of the burrow to moult and then mate. This increase in emergence duration provokes a corresponding rise in the chance of an animal's capture by trawling over this period (Bell *et al.*, 2006; Aguzzi and Sardà, 2008). A consequent underestimation in assessment by trawling occurs in autumn/winter for the opposite reason. In autumn and winter, berried females do not emerge for feeding and their availability is largely

reduced. Emergence is modulated not only by the stage of the reproductive cycle but also by size. Juveniles rarely emerge within the first year, and therefore, instances of their capture are consistently low (Sardà and Aguzzi, 2012). This unavailability of small size individuals may be compared to the bias pointed out in UWTV surveys relative to multiple occupancy of the burrows with juvenile and adult *Nephrops* cohabitating.

In the deep grounds of FUs 28 and 29, the hauls are carried out in spring-summer during daytime, where the emergence is higher.

6 Analysis

The analysis of the survey data have been done by subarea and depth strata.

7 Reporting of results

7.1 Survey summary sheet

A survey summary sheet should be provided for each survey. The following may serve as an example:

Country		Vessel Name	
Survey Name		Dates (start/end)	
FU / Ground Name			
Number of staff			

Objectives:

Survey Design	
Gear details	
Number of stations (planned/completed)	
Trawl horizontal opening (m)	
Trawl vertical opening (m)	
Doors / Wings spread	
Geometry of the net monitored by	

Deviations for the survey plan (e.g. coverage/weather related problems, technical problems, potential biases, etc.)	
Final abundance/biomass index (target and secondary species)	
CV (Relative standard error) (target and secondary species	
Other survey activities (CTD, Trawl, sediment samples, sediment profile images, etc.)	
Figures: Survey area map, spatial distribution of main species abundance index, LFDs, etc.	

8 References

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