WORKING GROUP ON NEPHROPS SURVEYS (WGNEPS; outputs from 2020)

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Contents

i Executive summary

The Working Group on *Nephrops* Surveys (WGNEPS) is the international coordination group for *Nephrops* underwater television and trawl surveys within ICES. This report summarizes the national contributions on the results of the surveys conducted in 2020 together with time series covering all survey years, problems encountered, data quality checks and technological improvements as well as the planning for survey activities for 2021.

In total, 19 surveys covering 25 functional units (FU's) in the ICES area and 1 geographical subarea (GSA) in the Adriatic Sea were discussed and further improvements in respect to survey design and data analysis standardization and the use of most recent technology were reviewed. Due to the COVID-19 pandemic there were disruptions across several functional units to: survey operations (FU 30, GSA 17, FU 10, FU 13 – Jura, FU 34, FU 28-29); data processing (FU 23-24) and survey coverage (FU 9).

Further results from field studies on behaviour aspects of burrow emergence using bottom cages monitored by an automated camera system and on short-range migration using acoustic tracking and remote operated vehicle (ROV) surveys in marine protected areas have become available and are summarised in this report.

Geostatistical investigations to reduce uncertainty estimates showed comparable results to historical trends for one survey area in the North Sea. Other preliminary work to redefine survey area using best available datasets was also discussed.

Reference sets compilation and count evaluations using still image annotations and Lin's concordance correlation coefficient (CCC) quality control were presented.

Automatic burrow detection based on deep learning methods applied to a test dataset with annotated burrow counts from a HD camera system from two projects showed promising results. The working group members were encouraged to provide more material with annotated burrow counts for further development of machine learning tools.

An underwater television (UWTV) survey manual has been accepted for publication in the ICES Techniques in Marine Environmental Sciences (TIMES) series. The working group is currently developing plans for a *Nephrops* UWTW database to be established at the ICES data centre.

ii Expert group information

Expert group name	Working Group on *Nephrops* Surveys (WGNEPS)
Expert group cycle	Multiannual
Year cycle started	2019
Reporting year in cycle	2/3
Chair(s)	Jennifer Doyle, Marine Institute, Ireland
Meeting venue(s) and dates	17-19 November 2020, Online Meeting (Webex), 26 participants

iii Terms of Reference

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	To review any changes to design, coverage and equipment for the various *Nephrops* UWTV and full-scale trawl surveys since 2018 and to update the Series of ICES Survey Protocols (SISP) as required	To ensure surveys used by WGCSE, WGBIE and WGNSSK are fit for purpose.	3.1, 3.2	Recurrent annual update	Survey summary including and description of alterations to the plan, to relevant assessment-WGs (WGCSE, WGNSSK, WGBIE) and SCICOM. Planning of the upcoming surveys for the survey coordinators and cruise leaders, and update the SISP accordingly if necessary.
b	Develop an international database for *Nephrops* UWTV survey data which will hold burrow counts, ground shape files and associated data.	There is a need to centralize UWTV data in a single international database. Ensure data is available externally.	3.5	Year 1-3	ICES database
c	Update R scripts for *Nephrops* UWTV survey data processing including functions to quality control, analyze and visualize data, and interface the tools with the international database for *Nephrops* UWTV survey data	Improving standardisation of data QC and data processing. Support new developing surveys on data analysis.	3.1	Recurrent annual update	Document and R packages for UWTV survey data on github site.
d	To review video enhancement, video mosaicking, automatic burrow detection and other new technological developments applied in *Nephrops* UWTV surveys and to update the Series of ICES Survey Protocols (SISP) as required .	WGNEPS should periodically review emerging technologies that might improve survey methodologies.	4.1	Recurrent annual update	To update the SISP based on conslusions if necessary. Other publications when appropriate.
e	Review and report on the utility of UWTV and trawl *Nephrops* surveys as platforms for collecting data for purposes other than *Nephrops* assessment (e.g. 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.	1.5	Year 2	Joint workshop/meeting report with users

f	Analyse existing data from UWTV and trawl *Nephrops* surveys to evaluate possible factors affecting burrow emergence of *Nephrops* (e.g. currents and light)	Recent behaviour aspects have been investigated in the laboratory. Important to investigate correlation with field data.	1.3	Year 3	Review paper

iv Work Plan Summary

Year	Summary
Year 1	All ToRs will be adressed in this year but the the main task in year 1 will be to establish the UWTV database and to provide updated shape files of Nephrops FUs and survey domains (ToR b)
Year 2	All ToRs will be adressed in this year. In addition to this focus will be on ToR e in year 2
Year 3	All ToRs will be adressed in this year. Focus in year 3 will be on new technologies and, if appropriate, an up-date of the SISP (ToR b) as well on the review of field date on factors affecting burrow emergence and occu-pancy (ToR f)

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	12-14 November	Split, Croatia	1st Interrim report by 6 January to EOSG	Election of new chair(s)
Year 2020	17-19 November	Online meeting (Webex)	2nd Interrim report by 17 Decem-ber 2020 to EOSG	Change of chairs: Outgoing: Kai Wieland and Adrian Weetman Incoming: Jennifer Doyle
Year 2021	16-18 November	Cadiz, Spain	Final report by 1 February 2022 to EOSG	

1 Survey coordination (ToR a)

The 2020 meeting was held by webex due to the COVID-19 pandemic situation. In total, 19 surveys covering 25 functional units (FU's) in the ICES area and 1 geographical subarea (GSA) in the Adriatic Sea (Figure. 1.1) were discussed and further improvements in respect to survey design and data analysis, standardization and the use of most recent technology were reviewed. Survey details are provided in annex 3.

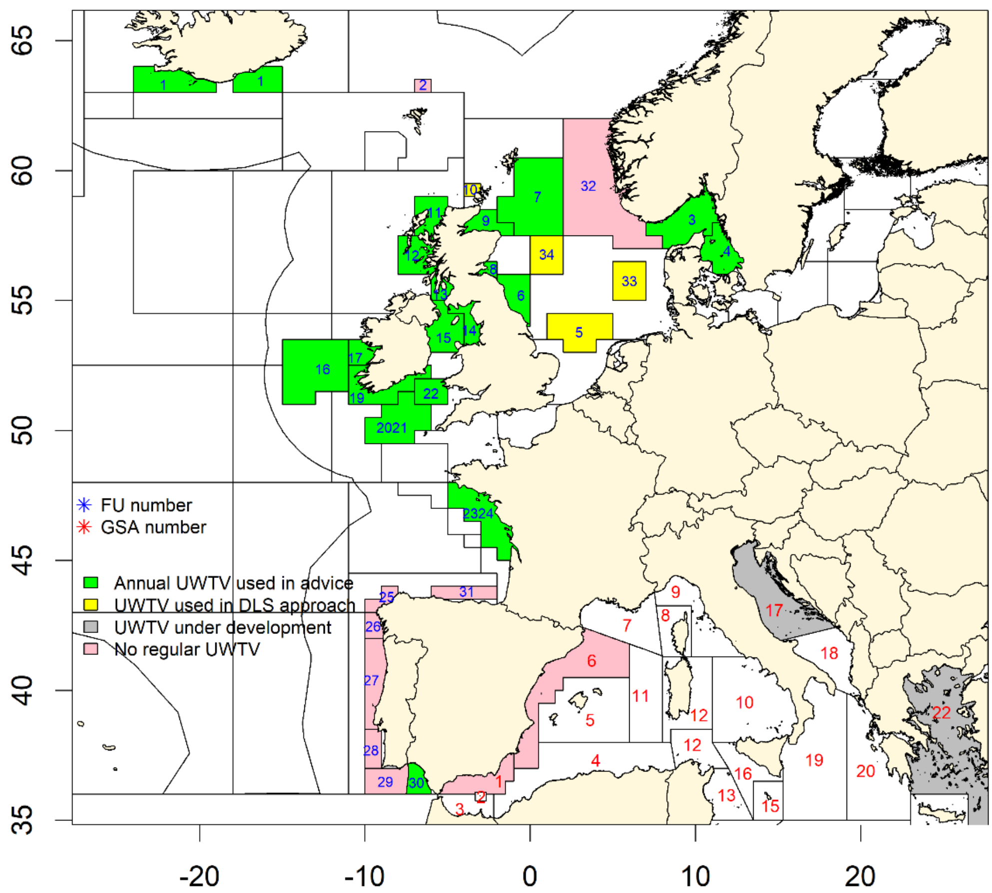

Figure. 1.1 *Nephrops* UWTV survey areas and use in stock assessment (FU: Functional Unit, GSA: Geographical Sub Area, DLS: Data Limited Stock).

There were some disruptions to 2020 survey operations and data processing due to COVID-19 pandemic situation and these are summarised below:

- Five UWTV survey areas were not completed in 2020, that is, FU 30 (Gulf of Cadiz), Pomo Pits GSA 17, FU 13 (Sound of Jura), FU 10 (Noup) and FU 34 (Devil's Hole).
- UWTV survey FU 9 (Moray Firth) was completed in 2020, however, issues including the coverage, limited number of stations and counter variability resulted in the data being deemed unusable for full stock assessment purposes.
- UWTV survey FU 23-24 (Bay of Biscay) was completed, however, burrow count data were incomplete as based on one reviewer only for the majority of the stations. This dataset was used in the final analysis and to calculate stock abundance and advice.
- FU 28-29 (South Portugal) trawl survey was not completed.

Survey series by Functional Unit / GSA are shown in Figure 1.2. Tentative survey schedule for 2021 is given in Figure. 1.3. Time series of *Nephrops* abundance estimates for the FU's are shown in Figure. 1.4a-d.

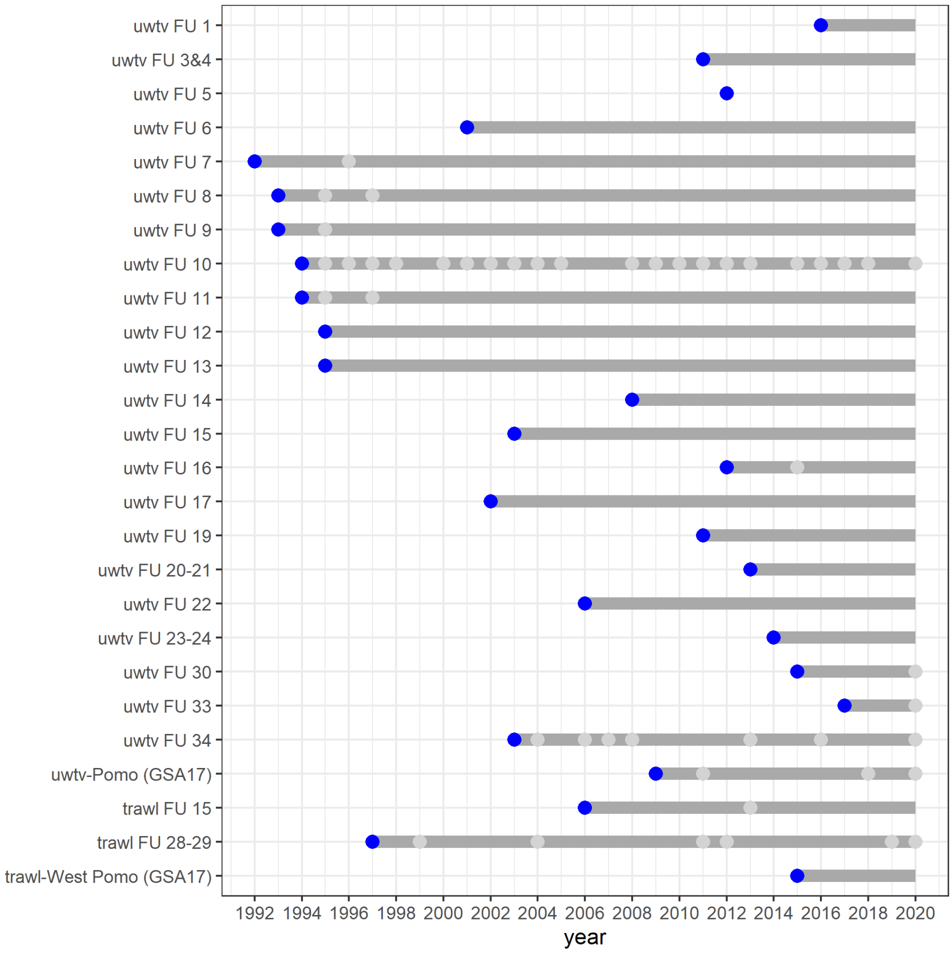

Figure. 1.2 Survey series by *Nephrops* Functional Units / GSA. Blue dot indicates first year of survey, light grey dot indicates year in which survey was not conducted and grey line shows the survey series.

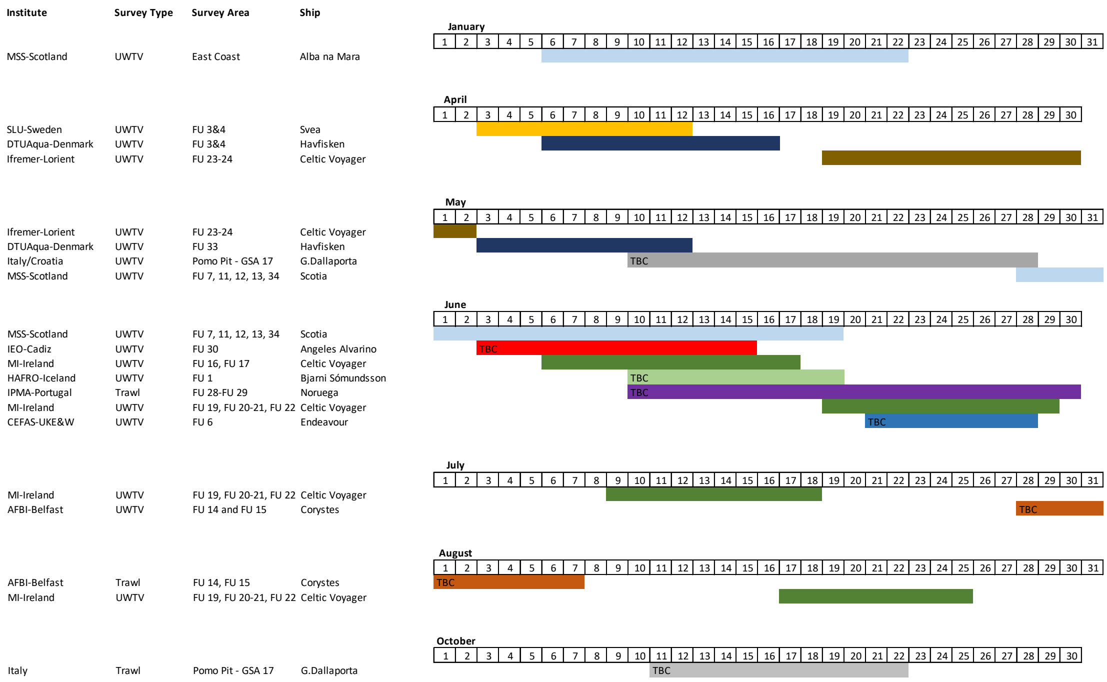

Figure. 1.3 *Nephrops* survey schedule for 2021.

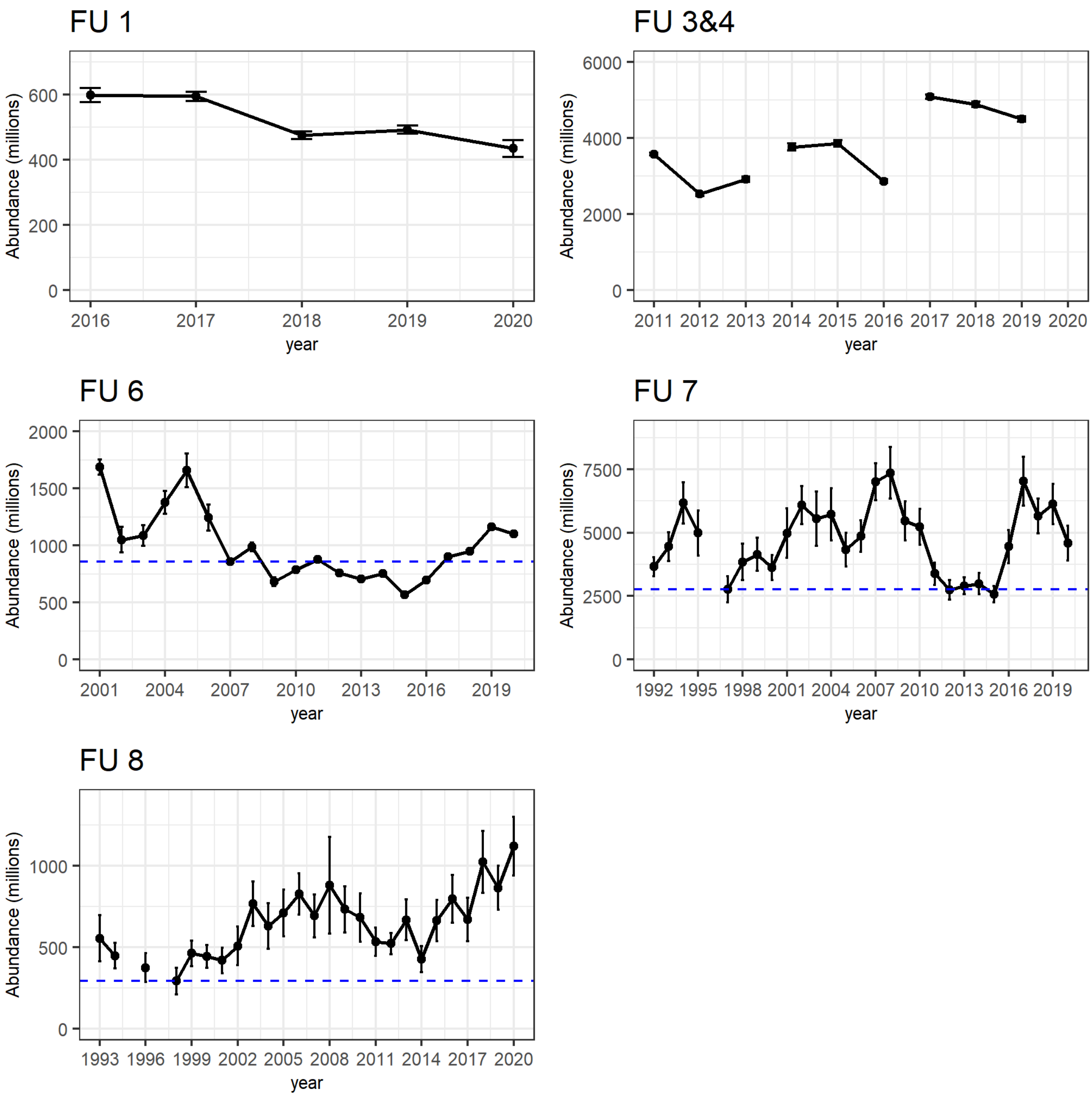

Figure. 1.4a *Nephrops* abundance (with 95 % confidence interval) in FU 1, FU 3&4 (breaks indicate extension of the survey area). Dashed line shows proxy for MSY reference point $B_{trigger}$.

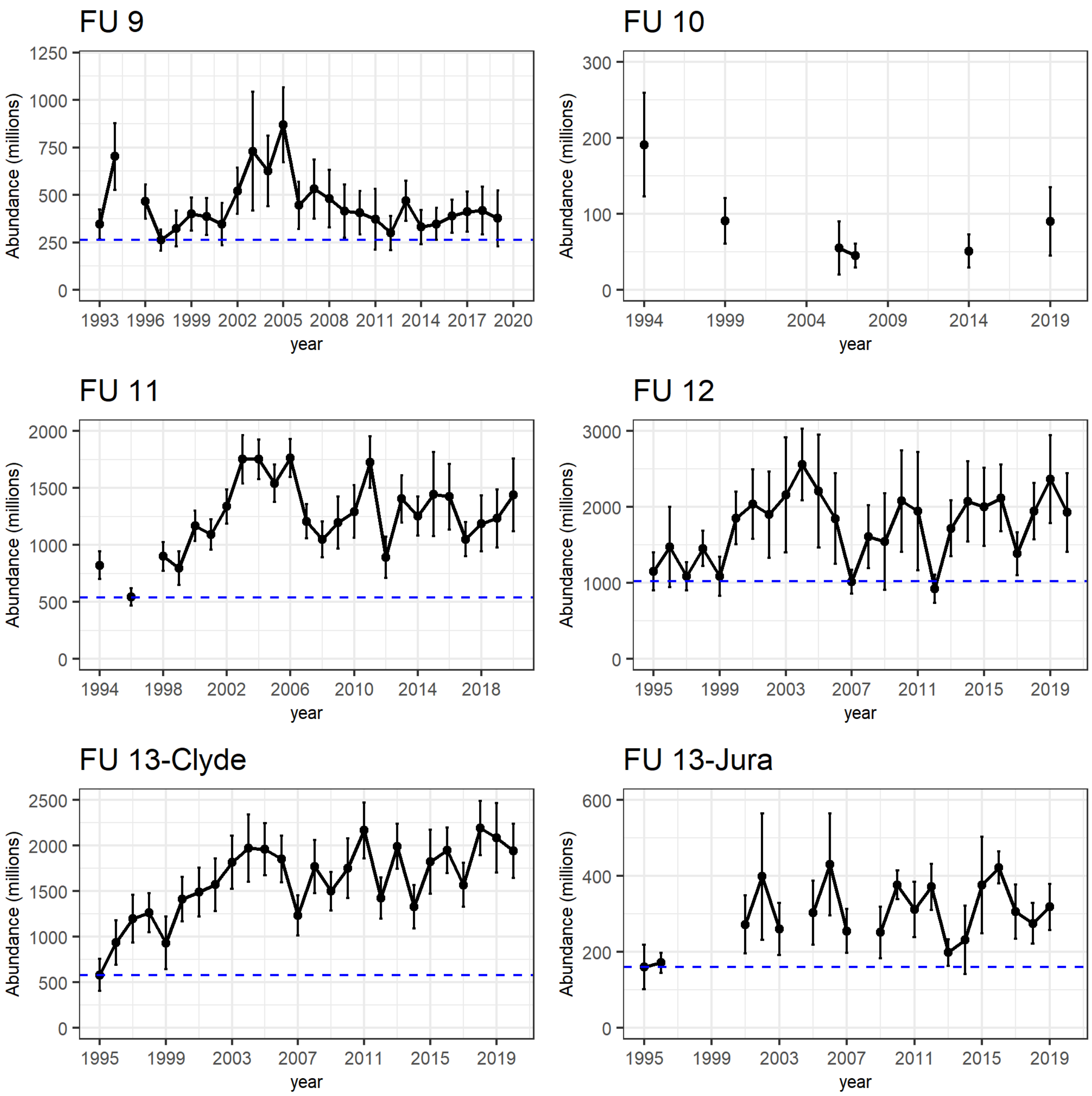

Figure. 1.4b *Nephrops* abundance (with 95 % confidence interval) in FU 9, FU 10, FU 11, FU 12, FU 13-Clyde and FU 13-Jura. Dashed line shows proxy for MSY reference point $B_{trigger}$.

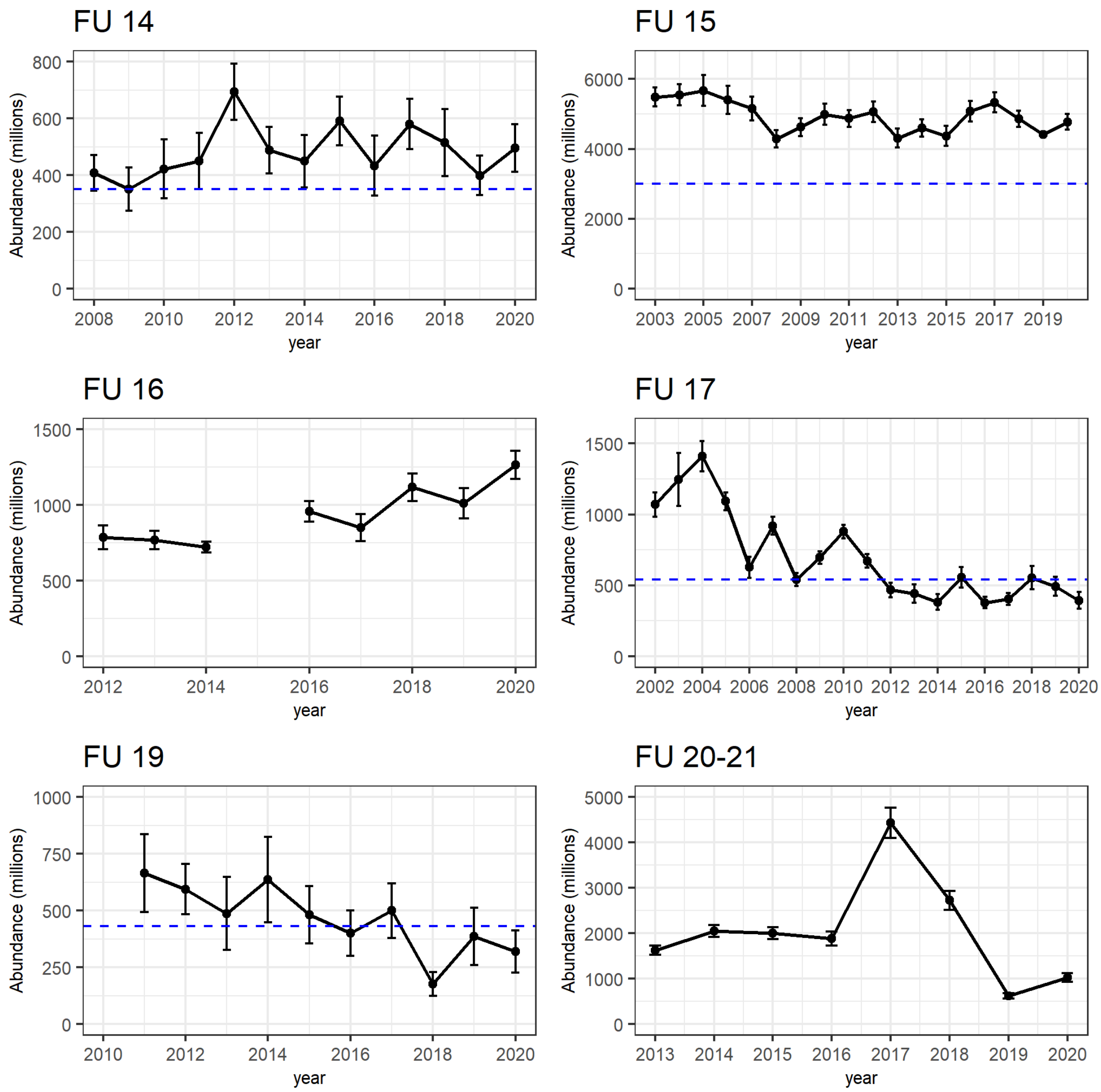

Figure. 1.4c *Nephrops* abundance (with 95 % confidence interval) in FU 14, FU 15, FU 16, FU17, FU 19 and FU 20-21. Dashed lines show proxy for MSY reference point $B_{trigger}$.

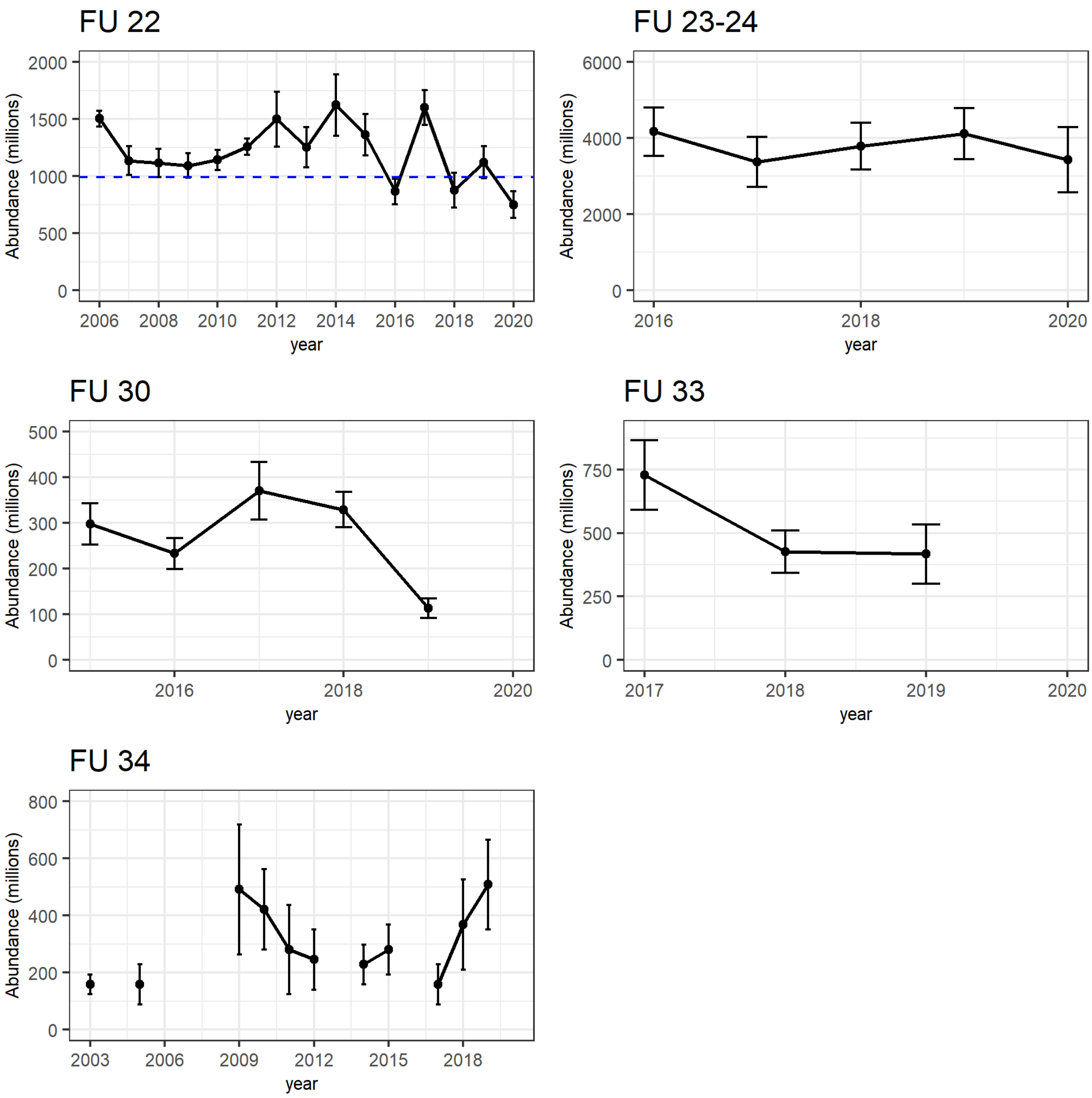

Figure. 1.4d *Nephrops* abundance (with 95 % confidence interval) in FU 22, FU 23-24, FU 30, FU 33 and FU 34. Dashed lines show proxy for MSY reference point $B_{trigger}$.

The conclusions for future work are as follows:

- WGNEPS recommends continuing with the use of high definition camera systems and still images with the objective to annotate images so that deep learning algorithms can be developed in future to identify features.
- WGNEPS recommends promoting and facilitating when possible on UWTV surveys, staff exchange from national laboratories.
- WGNEPS recommends promoting and facilitating when possible on UWTV surveys, staff exchange from other institutes who may use survey data.
- WGNEPS recommends that national laboratories invest effort in calculating mean burrow size for specific grounds. The edge effect calculation is based on field of view (FOV) and burrow diameter. Mean burrow diameter can vary a lot over time for most grounds and this could have an impact on the edge effect. This will be added as a term of reference for this working group.
- WGNEPS recommends exchange of technical expertise so that new and developing surveys may benefit from others.
- WGNEPS agrees that it is mandatory that each station is read by at least two readers in accordance with agreed survey data processes. If there are any deviations to survey data work-up this is to be flagged prior to the time the data are to be used for assessment to the stock co-ordinator and chair of the relevant assessment working group.

2 Technological developments (ToR d)

2.1 Burrow emergence rhythms of Nephrops norvegicus: UWTV, surveying biases and novel technological scenarios

Aguzzi J., Bahamon N. and O'Malley C., Berry A., Gaughan P., Doyle J., Lordan C., Tuck I.D., Chiarini M., Martinelli M., Marini S., Thomsen L., Flögel S., Albiez J., Torkelsen T., Pfannkuche O., Rune Godo O., Henning W., Lopez-Vasquez V., Zuazo A., Rodriguez E., Valencia J., Calisti M., Stefanni S., Mirimin L., Del Río J.,Francescangeli M., Fahalazed A., Navarro J., Vigo M., Masmitjia I., García J.A., Chumbinho R., Company J.B.

The occupancy assumption "one burrow system, one animal" (Sardà and Aguzzi, 2012) raises a number of generic research questions concerning the true occupation of burrows in many Nephrops stocks. The burrow system acts as the centre of a strong territorial rhythmic behaviour (Rice and Chapman, 1971; Farmer, 1975) leading the adults' lobsters to evict subordinates from burrows in a dominance hierarchy framework (Sbragaglia et al., 2017); indeed, two wild adult lobsters are rarely found in the same shelter (Cobb and Wang, 1985). Other studies showed evidence that no spatial segregation occurs between juveniles and adults (Maynou and Sardà, 1997) achieving the establishment of adult-juvenile complexes (at least 1 adult and 1 juvenile per burrow), which become separated as juveniles grow (Tuck et al., 1994). Moreover, Nehprops burrows systems could also be inhabited by other benthic crustacean species (e.g. Munida sp.) or may remain empty and intact for an unknown period of time after animals' death (Sardà and Aguzzi, 2012). These factors still create uncertainties about the true numbers of animals occupying burrow systems, representing an important issue when providing a relative or absolute index for determination of Nephrops' stock status (i.e. Harvest Rate; Sardà and Aguzzi, 2012).

For a better tuning of the occupancy assumption "1 burrow system, 1 animal", an accurate temporal description of burrow emergence rhythmicity should be provided. The diel rhythm of burrow emergence can be subdivided in three different phases (Aguzzi et al., 2003, 2007): full emergence, full retraction and door-keeping (i.e. an intermediate period in which individuals wait at the burrow entrance; Sbragaglia et al., 2015). In Aguzzi et al. (submitted) more than three thousand video transects reporting densities by depth of full emergence and door-keeping animals and burrow systems collected in past decades around Ireland waters, are analysed. All density data were grouped per depth ranges based on both the available ones and the previous knowledges from trawl catch patterns (Aguzzi et al., 2003) as nominal: 15-50, 51-100, 101-160 and 340-570 m. A waveform analysis on UWTV survey data were conducted to describe averaged full emergence and door-keeping behavioural rhythms over the 24-h within the established depth range. Such an analysis indicate that Nephrops full emergence varied from nocturnal toward midday hours with increasing depth of sampling, while door-keeping behaviour coincided with full emergence only on the upper shelf (15-50 m depth) and the shelf-break (101-160 m depth). To further improve the analysis GAM models for emergence and door-keeping behaviours by depth range were developed as well. The statistical model result by GAM revealed an overall pattern of full emergence and door-keeping behaviour similar to that found by the previous waveform analysis. The emergence behaviour is predominantly dusk and dawn-oriented above 50 m, bimodal and tending to be diurnal between 50 and 100 m, temporally diffused between 101 and 160 m, and finally fully diurnal between 340 and 570 m. The door-keeping behaviour is only temporally defined above 50 m (being nocturnal) and bimodal with a nocturnal increase between 100-160 m. Finally, estimated densities of visible animals engaged in both emergence and door-keeping behaviours (i.e. all individuals) were compared with burrow system counts and derived density estimates, to provide evidence putative biases to the standard stock assessment assumption that "1 burrow system is occupied and maintained by one animal" (Leocadio et al., 2018). A temporally integrated chart of all waveform and GAM results shows an average of about 1 visible individual per 10 burrows, at most, suggesting that a high proportion of the population remains cryptic even during periods of peak emergence.

In last years, the novel technologies have become increasingly common in fish-stock assessment using video imagery from worldwide cabled observatory networks (Aguzzi et al., 2020; Del-Rio et al., 2020). The novel scenarios allow to collect observations on visible Nephrops individuals as well as their burrows through cabled observatory instrumented fields for ecological monitoring of fishery resources (e.g. OBSEA-www.obsea.es; and SmartBay Observatory-https://www.smartbay.ie/). Hence, the next steps for fishery-independent assessment calibration should be focused on new advanced imaging packages used on autonomous robotic platforms (e.g. crawlers, AUVs and stand-alone cameras) to tune the fishery-independent assessment equation "1 burrow-1 animal".

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Tuck, I. D., Atkinson, R. J. A., and Chapman, C. J. 1994. The structure and seasonal variability in the spatial distribution of Nephrops norvegicus burrows. Ophelia, 40.

2.2 Creel fishing and acoustic tracking trials in the No-Take zone off Palamós-Roses (Northwestern Mediterranean Sea) at 350-420 m depth.

Maria Vigo, Joan Navarro, José A. García, Jacopo Aguzzi, Guiomar Rotllant , Nixon Bahamón and Joan B. Company

Marine Protected Areas (MPAs) have proven to be useful tools for conservation (Day et al., 2019), and they can offer many other benefits such as improving commercial fish stocks, including habitat restoration (Kerwath et al., 2013; Langton et al., 2020). In the context of the Spanish research project called RESNEP (CTM2017-82991-C2-1-R, "Marine no-take areas as a tool to recover iconic Mediterranean fisheries in decline: the case of *Nephrops norvegicus*"), a pilot marine reserve was established in an overfished ground at 350-400 m depth in the NW Mediterranean Sea, where Norway lobster (*Nephrops norvegicus*) dominated the target species fished by local and regional fisheries (BOE-A-2020-9015). Norway lobster constitutes an iconic fishing resource for European fisheries (Leocádio et al., 2012), whose landings have diminished the last two decades, especially in deep-water overfished benthic Mediterranean ecosystems (García-De-Vinuesa et al., 2020; Piroddi et al., 2020). The main objective of this marine no-take reserve, stablished on 2017, was to recover the population of Norway lobster as well as the recovery of the benthic assemblage and the habitat state.

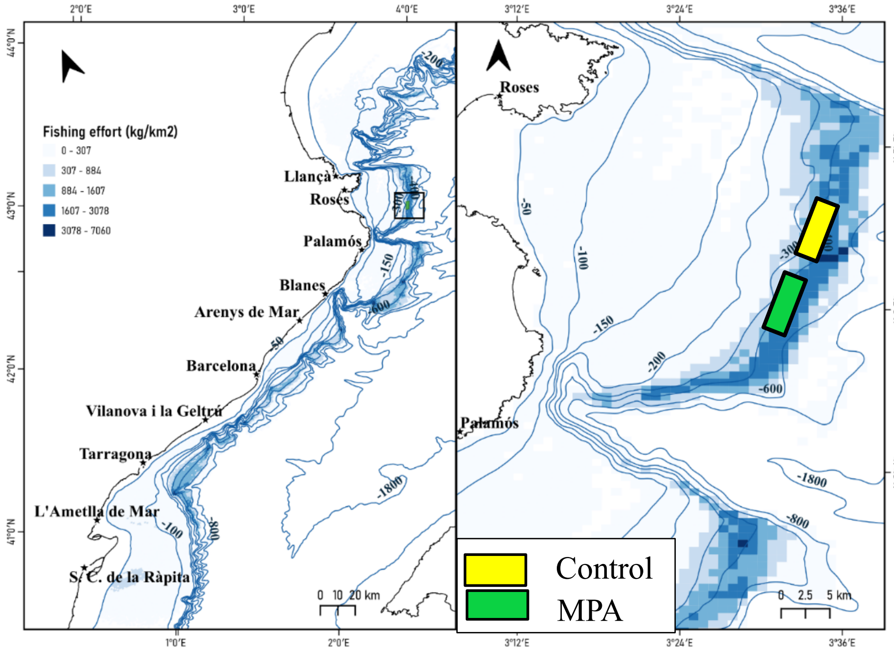


Figure 1. Spatial distribution of Norway lobster catches along the Catalan coast, and the location of the marine no-take reserve (green square) and the control area (yellow square) where the visual transects with ROV have been performed. The blue gradient indicates the accumulated catches of Norway lobster between 2006-2019.

In the present communication, we present the preliminary results related to the ecological effects of the marine no-take reserve, after 3 years of implementation using ROV (Remotely Operated Vehicle) visual census, a non-invasive monitoring method. For this purpose, we conducted 24 h visual transects in the marine reserve and in a control area where fishing activity is still undergoing. These visual transects were performed in February 2020 on board R/V Sarmiento de Gamboa (Figure.2)

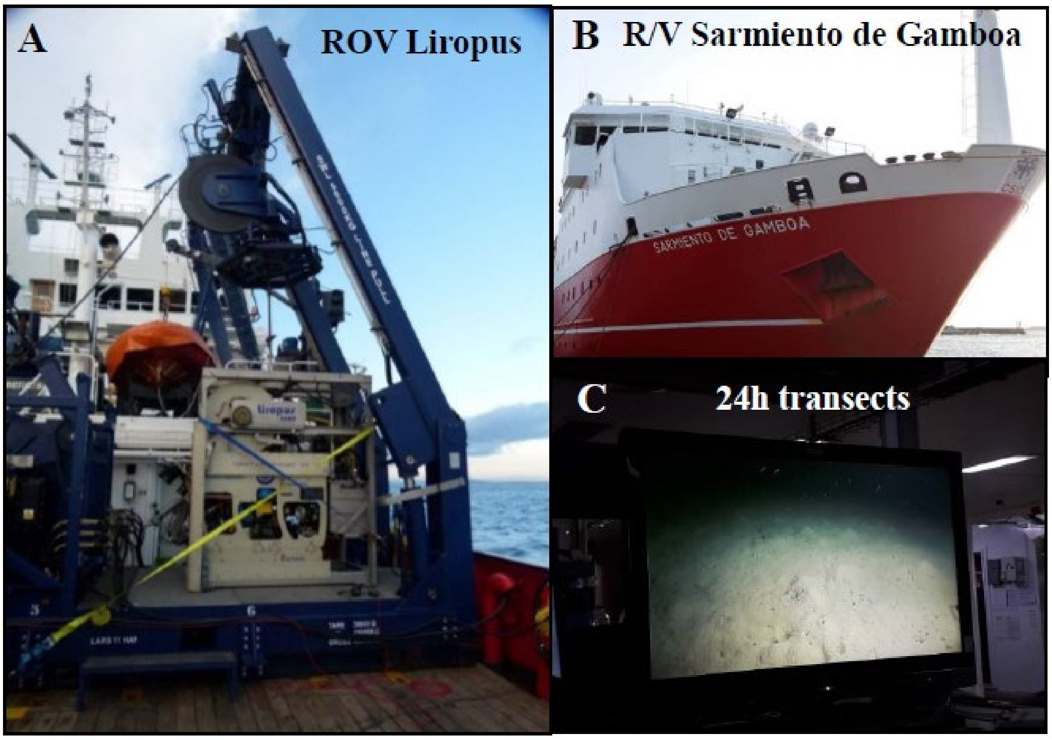


Figure 2. The Remotely Operated Vehicle (ROV) Liropus tfhat was used to performed all visual transects (A). The Research Vessel Sarmiento de Gamboa (B). The monitor in which the 24h visual transects were transmitted to annotated all the species that appear (C).

During them, we assessed the abundance of Norway lobsters in the marine reserve and in the control area (Figure. 1). We will estimate, when was possible, the size of the individuals observed by calibrating the size with the scale of 10 cm provided by the ROV. Moreover, we annotated and classified the number of Norway lobsters located outside the burrows, or the ones performing door keeping behaviour (Aguzzi et al., 2007) in which we can see only the cephalotorax (Figure. 3). We also counted all the burrows, in presence of Norway lobsters or empty.

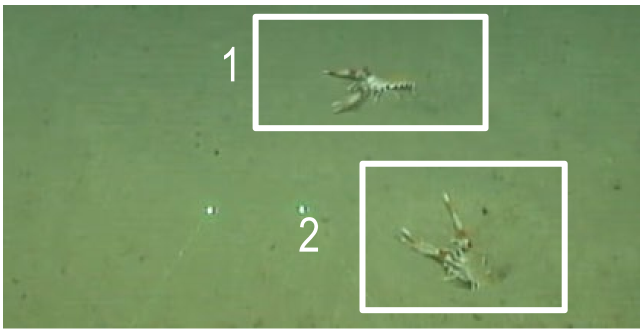


Figure 3. Behaviours studied in Nephrops norvegicus: 1: outside the burrows; and 2: door keeping behaviour.

Norway lobsters' abundance showed high numbers in the marine reserve than in the control area (Figure. 4). The temporal analysis of ROV census data showed that lobsters were mainly outside their burrows during light hours, as previously confirmed in other studies (reviewed by Aguzzi & Sardà, 2008; Sardà & Aguzzi, 2012), being absent or at the tunnel entrance (i.e. neither visible as door keeping) at the darkness.

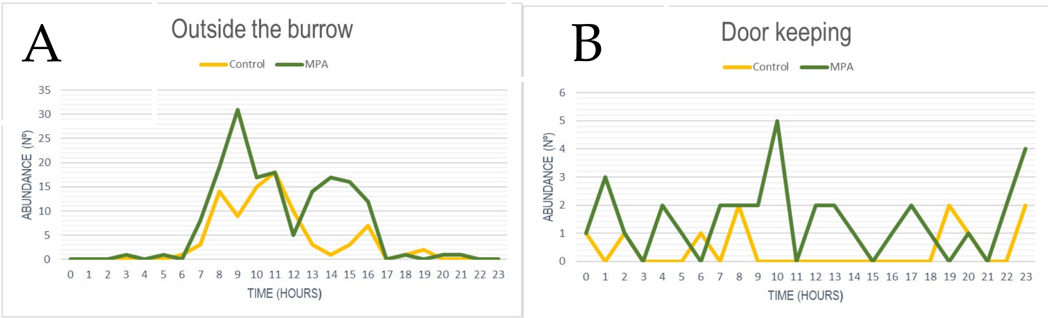


Figure 4. Firsts results of diel activity of Norway lobster obtained with visual transects with ROV. Abundance of Norway lobster outside the burrow along the day (A). Abundance of Norway lobster doing door keeping behaviour along the day (B). The total swept area covered by the ROV is the same in both control and MPA areas being approximately 0.02km^2.

In addition to Norway lobster, our objectives were also to identify all the species that appear in both areas and measure the individuals (Figure. 5).

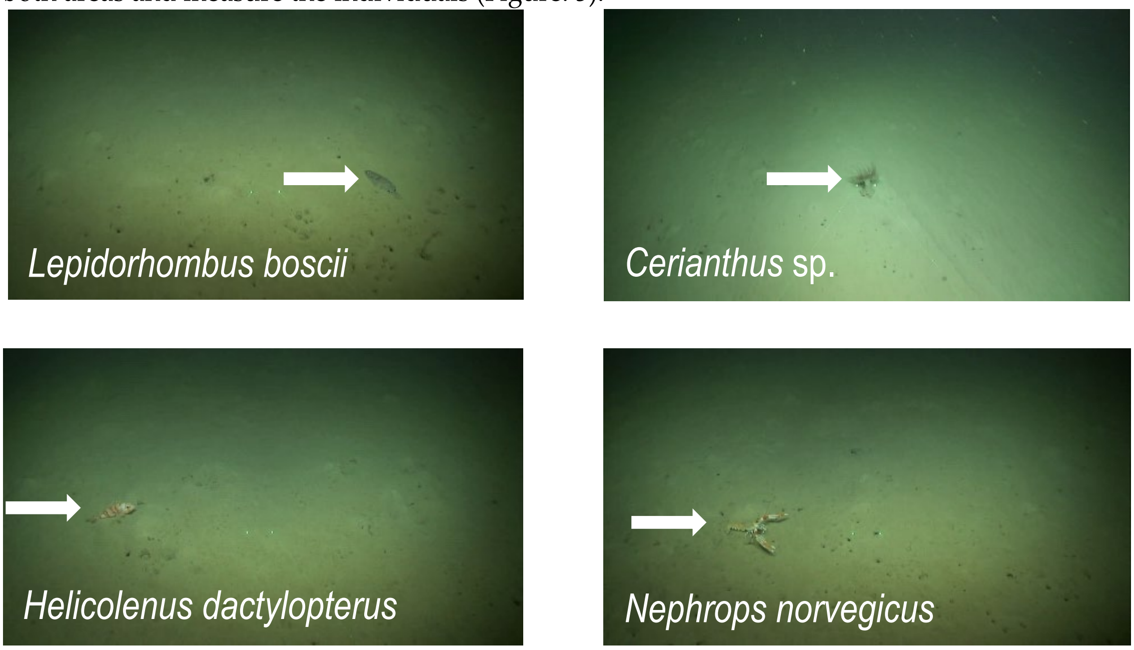
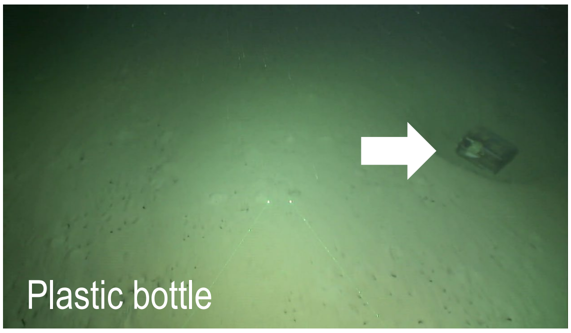
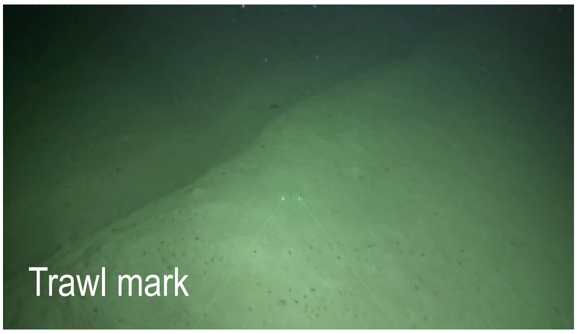


Figure 5. Examples of other species found in the marine reserve and the control area during the visual transects with ROV. Lasers indicate 10 cm.

In relation to the habitat state, the results showed that the control area presented alterations in the seabed, such as scraping and ploughing, directly associated with trawling activity. In contrast, the MPA showed a clear recovery of the benthos, evidencing the presence of well-structured burrow systems of Norway lobsters. We are annotating also all the debris that appear in both areas (Figure. 6)





In conclusion, our results suggest that the implementation of marine no-take reserves could be an effective strategy contributing to recover the population of Norway lobster and other demersal species by reducing fishing pressure and promoting restoration of their habitats.

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2.3 Acoustic tracking of *Nephrops norvegicus* by net-worked moored hydrophones in a deep-sea no-take reserve of the North Western Mediterranean Sea.

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Joan Navarro, María Vigo, Jacopo Aguzzi, Nixón Bahamón, José Antonio García, Guiomar Rotllant, Joan B. Company; Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain.

Knowing the displacement capacity and mobility patterns of fished marine resources is pivotal to establish effective conservation management strategies in marine ecosystems. Accurate behavioural information of deep-sea fished ecosystems is necessary, but currently scarce, to establish the sizes and adequate locations of marine protected areas within the framework of large international societal programs (e.g. European Community H2020, as part of the Blue Growth economic strategy). A breakthrough in the autonomous capability of mobile platforms to deliver data on animal behaviour beyond traditional fixed platform capabilities (e.g. cabled observatories) is overcoming these limitations. Here, we present useful example of that potential in relation to the implementation of autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) as an aid for acoustic long-baseline localization systems for autonomous tracking of Norway lobster (*Nephrops norvegicus)*, one of the key resources exploited in European waters. We reported the outcomes of that monitoring in combination with seafloor moored acoustic receivers to detect and track the movements of 33 tagged individuals at 400 m depth over more than three months. We identified best procedures to localize both the acoustic receivers and the tagged-lobsters, based on cutting-edge algorithms designed for off-the-self acoustic tags identification. These procedures represent an important step forward for prolonged, *in situ* monitoring of deep-sea benthic animal behaviour at meter spatial scales.

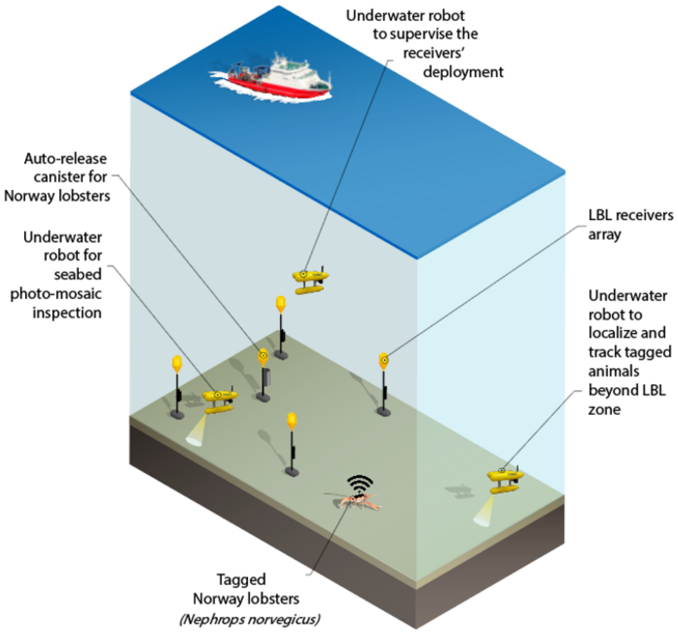

Figure 1. The strategy designed to track Norway lobsters (*Nephrops norvegicus*) is represented. Four receivers created an acoustic LBL localization system, where each one was in self-recording mode and was not accessed in real time. The tags transmitted periodically an acoustic ping, which was recorded by the static receivers and the underwater vehicles; both systems were used to track the lobsters' movements.

Static receivers for tracking purposes

The development of in situ, autonomous and permanent monitoring technologies delivering complex environmental information on habitat and species are being implemented worldwide (Aguzzi et al., 2019), serving the needs of policy decision (Danovaro et al., 2017) and the monitoring needed oriented to the fishery-independent stock assessment (Aguzzi et al., 2020). Acoustics monitoring of individuals play a major role in restoration via repopulation techniques, measuring home ranges and activity. For this purpose, tagged animals were deployed in June 2018 at 350-420 m depth, in a no-take reserve off Palamós-Roses coast (Figure 2A). Specifically, 33 *Nephrops* individuals were tagged with VEMCO transmitters connected by cyanoacrylate on the upper part of the cephalothorax (Figure 2B). The deployment area was equipped with 4 mooring lines, each holding a receiver for tracking signal presence (emergence)-absence (burial) and for triangulating animals' movement and efficiency in restoration procedures (i.e. tracking displaced ranges tom better tune the no-take zone surface area). The receiver's self-localization and clock's synchronization were computed using time of arrival (TOA) techniques. After these procedures, each tagged individual was localized using time difference of arrival (TDOA) methods. We tested different algorithms in order to characterize their performance and find the greatest (Masmitja et al., 2020). For example, in Figure 2C, the root mean square error (RMSE) position of a moving tag is presented, where the simulations were conducted using four static receivers. The figure shows the performance of the following algorithms: particle filter (PF), maximum a posteriori estimation (MAP), maximum likelihood (ML), weighted least square (WLS), and yet another positioning solver (YAPS).

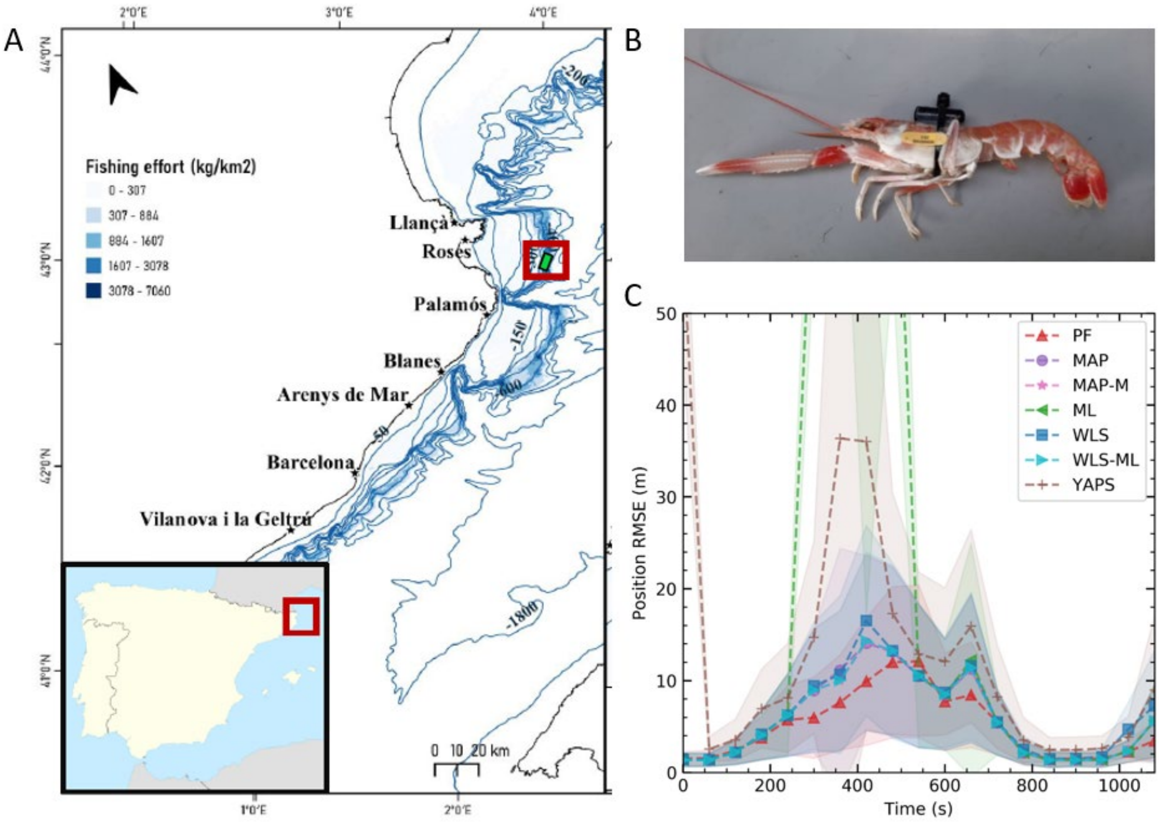

Figure 2. (A) Map of the study area in roses continental slope, northwestern Mediterranean Sea, where the Norway lobsters were tracked. The blue gradient indicates the accumulated catches of Norway lobster between 2006-2019. (B) a

tagged Norway lobster showing the VEMCO tag glued on its superior portion of the cephalothorax. (C) Performance of different algorithms to track acoustic tags using TDOA.

Underwater vehicles for tracking purposes

Moreover, we deployed an AUV and an ROV to also localize and track the tagged Norway lobsters. The flexibility of these vehicles overcome the limitations of traditional static receivers. To do so, we developed an innovative area-only target tracking (AOTT) method by the use of particle filter algorithms (Masmitja, et al. 2019). The AOTT method was characterized and tuned in order to obtain the greatest performance analytically and through simulations. In addition, different field tests were conducted previously to the Norway lobster campaign, at OBSEA observatory (www.obsea.es; Del Rio, et al. 2020) in Barcelona (Spain), and at Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing (CA, USA), Figure 3A and 3B respectively.

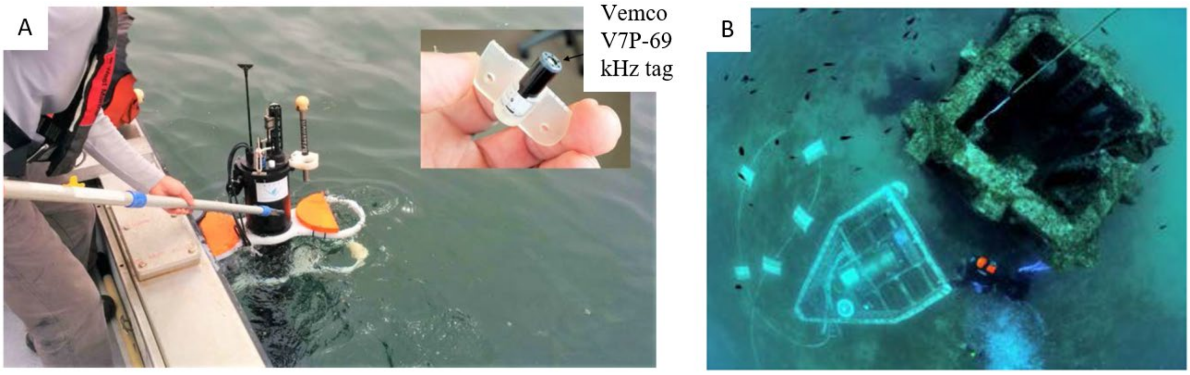

Figure 3. (A) Tests conducted at MBARI (Moss Landing, CA, USA). (B) OBSEA cabled observatory test site at 20 m depth, off Vilanova i la Gertrú (Barcelona, Spain).

The vehicles used during the campaign were the Super Mohawk II ROV and the Girona 500 AUV, Figure 4A and Figure 4B respectively. Finally, some of the results can be observed in Figure 4C, where the tracks conducted by both vehicles and the detected tags (T0…3) are represented.

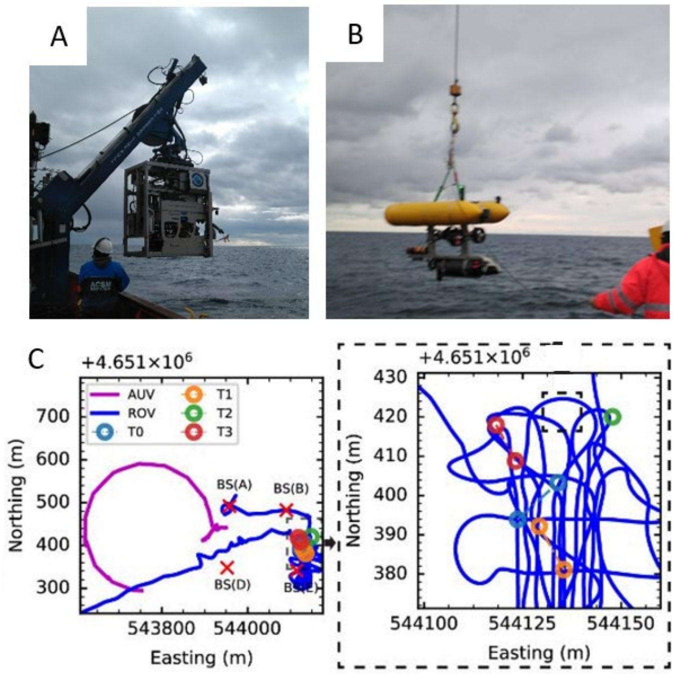

Figure 4. (A) Super Mohawk II ROV. (B) Girona 500 AUV. (C) tracks conducted by the vehicles and the detected tags (T0…3). The red crosses indicate the localization of the four moored Vemco receivers (BS)

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2.4 Training Neural Networks on *Nephrops* survey datasets

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2.4.1 The dataset

The dataset used is a set of 48 videos taken at sea in different stations, of which 46 are from the French Langolf 2019 survey and 2 from an Irish UWTV 2019 survey. For each station, images were recorded using a sledge (Figure. 1) for 10 minutes at 12 frames per second (around 7500 still images per station).

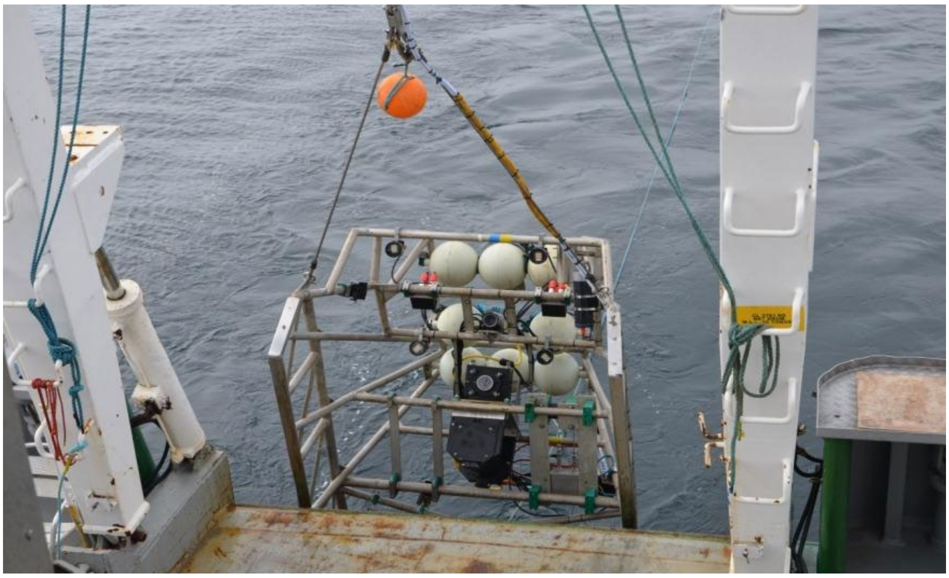


Figure 1: sledge used for the data acquisition

A personalized version of labelimg (https://pypi.org/project/labelImg/) was used to annotate the images. The annotation step consisted in drawing bounding boxes around regions of interest and assigning them a label (Figure. 2). The annotations are saved in XML in PASCAL VOC format, which is supported by most current detectors.

Figure 2 : Example of an image from LANGOLF-TV survey annotated within the modified labelimg environment

The number of annotations per species depends on their abundance on the stations (Figure. 3).

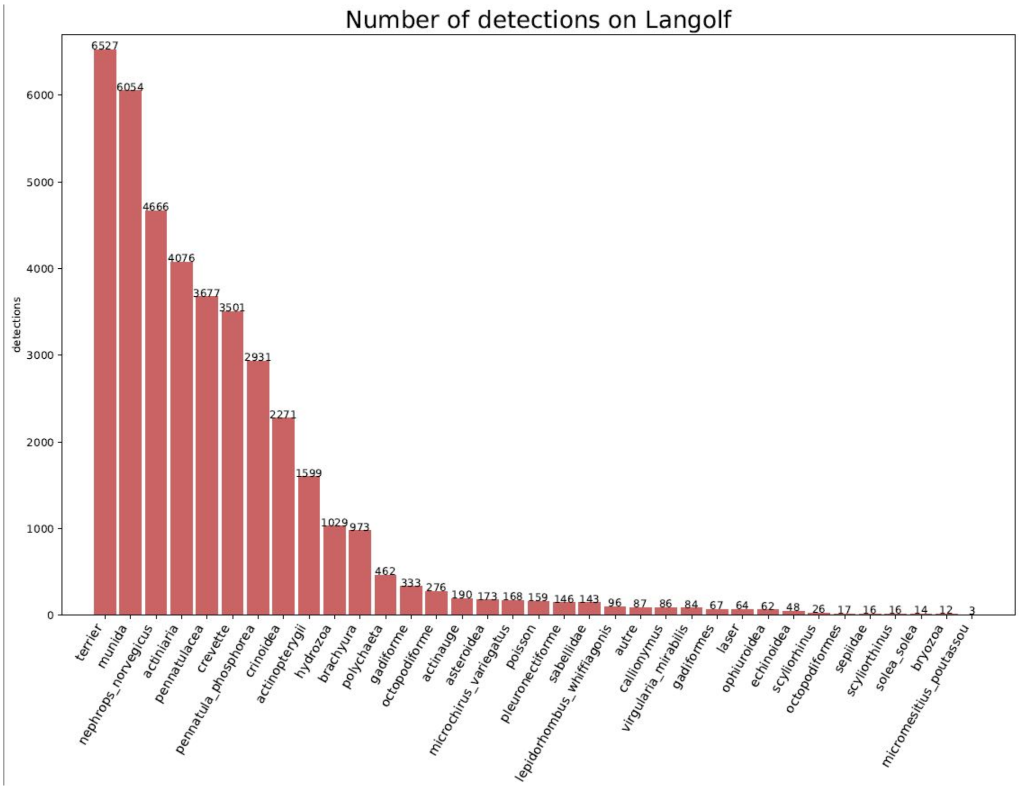


Figure 3: Number of annotations per classes (terrier=burrow)

2.4.2 The neural network

Different neural networks have been tested such as YOLOV3, FasterRCNN, SSD and EfficientDet. The neural networks used in this work is EfficientDet because it offers the best performances in precision, recall and time required per frame. The neural network has been fine-tuned to obtain better performances. For the moment, only 8 classes are used to train the neural networks: *Nephrops norvegicus*, pennatulacea, shrimp, actiniaria, crinoidea, munida, actinopterygi and the burrows. 43 videos are used for training, and contain a total of 16309 images with at least one annotation belonging to the 8 targeted classes.

2.4.3 Evaluating the neural network

Evaluating the Neural network consist in showing him an unseen station (during the training) and comparing its counts/species vs the counts of the humans. Evaluation data are from 5 reference stations (with images that do not contain any targeted species). It contains a total of 39,273 images.

Two evaluations were performed:

a. From the comparison between the neural network and the human analysis image per image using labelimg environment.
b. From the comparison between the neural network and the human analysis of the video at half speed.

2.4.3.a Comparison using the image per image method for the human analysis

The 5 stations have been fully analyzed image per image using the personalized labelImg. For each object the human could detect, a bounding box was drawn around the object, a class and an ID number were assigned. The human analysis image per image was considered as the ground truth. This method is very time consuming and not representative on the way the stations are usually analyzed.

The evaluation is made by mAP@0.5 (the 0.5 means that the intersection on the union between the detections and the ground truths must be at least 0.5). Table 1 contains the results on the tests data.

Results presented here are obtained with the following rules:

-TP : True Positive : If an ID is well classified (C) with a "confidence" > 0,6 on at least 2 frames and with an IoU* > 50% between the NN's ROI and the human's ROI
-FP : False Positive : If an ID classified (C) with a "confidence" > 0,6 on at least 2 frames and without an IoU* > 50% between the NN's ROI and the human's ROI
-FN : False Negative : If an object is not detected or detected with "confidence" >0,6 on less than 2 frames or without an IoU* > 50% between the NN's ROI and the human's ROI

- Precision: P = TP/(TP+FP)

- Recall: R = TP/(TP+FN)

- F1-score = 2x(PxR)/(P+R)

*IoU : Intersection over Union

The precision (P), the recall (R) and the F1 measure are calculated after a confidence threshold of 0.6 on at least 2 frames.

Classes	TP	FP	FN	P	R	mAP0,5	F1
all	564	535	408	0,513	0,58	0,385	0,544
nephrops_norvegicus	86	27	12	0,761	0,878	0,652	0,815
pennatulacea	136	70	14	0,66	0,907	0,331	0,764
shrimp	12	2	69	0,857	0,148	0,284	0,252
actiniaria	37	11	32	0,771	0,536	0,656	0,632
munida	96	7	35	0,932	0,733	0,471	0,821
actinopterygii	31	25	11	0,554	0,738	0,421	0,633
burrow	166	391	235	0,298	0,414	0,259	0,347

Table 1: Results on stations 2, 8, 69 (LANGOLFTV19) and 115, 145 (UWTV19)

2.4.3.b Comparison watching the video at half speed

Each of the 5 stations have also been analyzed by 4 humans using VLC player and watching the video at half speed. For each object the humans could detect, the video was paused, the data (time, specie, number…) was reported in an excel sheet. This method is more representative of the usual method for analyzing the videos. However, in some case, some objects are not detected by the humans as the sledge is moving too fast or as the objects are in the shadow. In this study, the 4 humans analyzed the 5 stations in order to have the inter-observer variability and to compare the counts of the neural network (Figure. 4) to the counts of the 4 humans. The burrows counts are reported table 2. It appear that the neural network is over counting. This is mainly due because the neural network is counting the burrows and not the complexes while humans count the complexes.

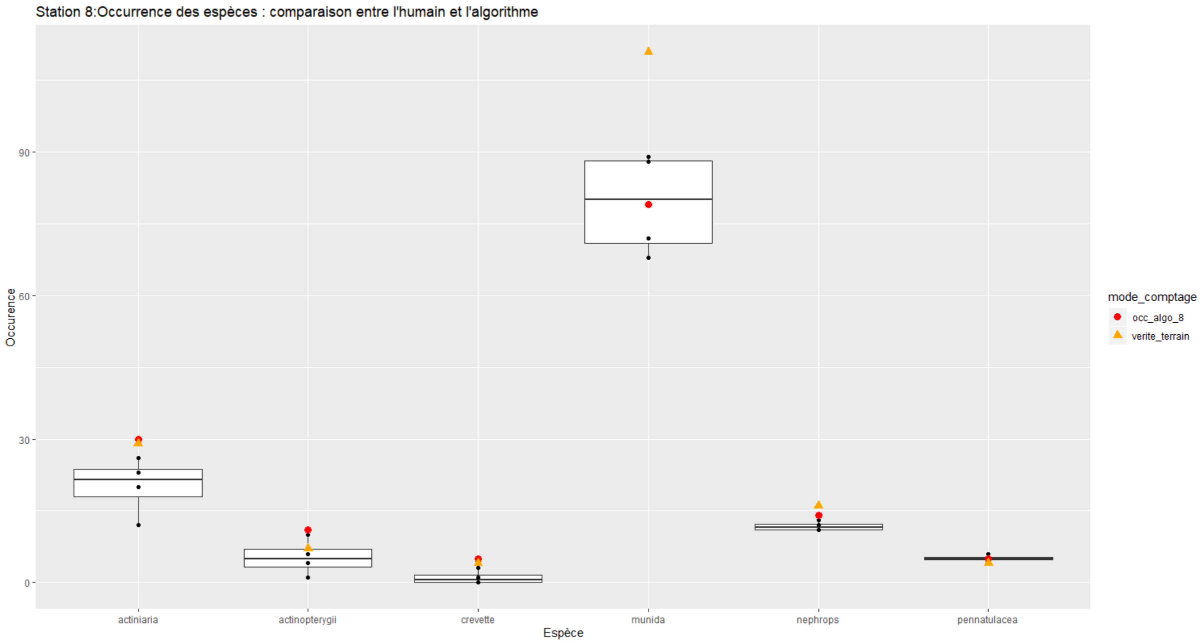


Figure 4: Comparison between humans counts of different species. Black dots = the humans count watching at half speed, red dots = neural network counts, orange triangle = ground truth (human counts image per image)

Station	Counter 1	Counter 2	Mean	Neural Network
Stn2_LANGOLF19	36	30	33	31
Stn8_LANGOLF19	100	95	97,5	100
Stn69_LANGOLF19	13	16	14,5	5
Stn13_LANGOLF20	166	178	172	187
Stn145_LANGOLF20	124	130	127	208
Stn167_LANGOLF20	68	74	71	90

Table 2: Burrow counts results from different stations

2.4.4 2.4.4 Examples of objects identified and confidence threshold number

Figure. 1 and 2 show *Nephrops* burrows identified and associated confidence threshold number. Figure. 3 shows *Nephrops norvegicus* and *Munida* species identified with confidence number.

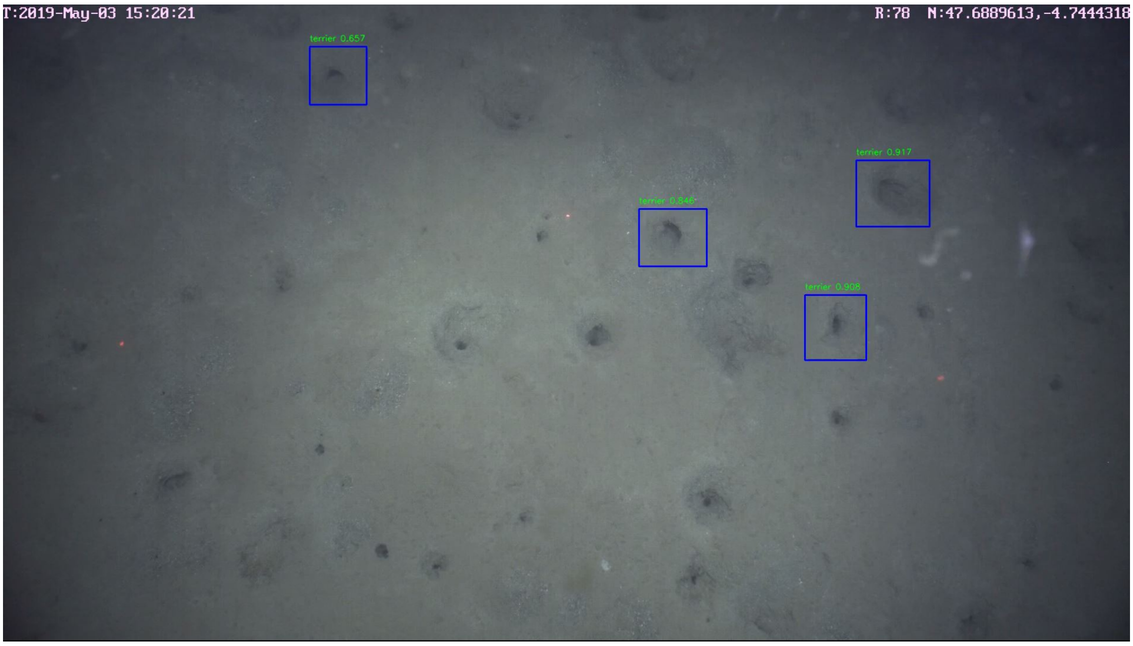


Figure 1. Still image from neural network programme.

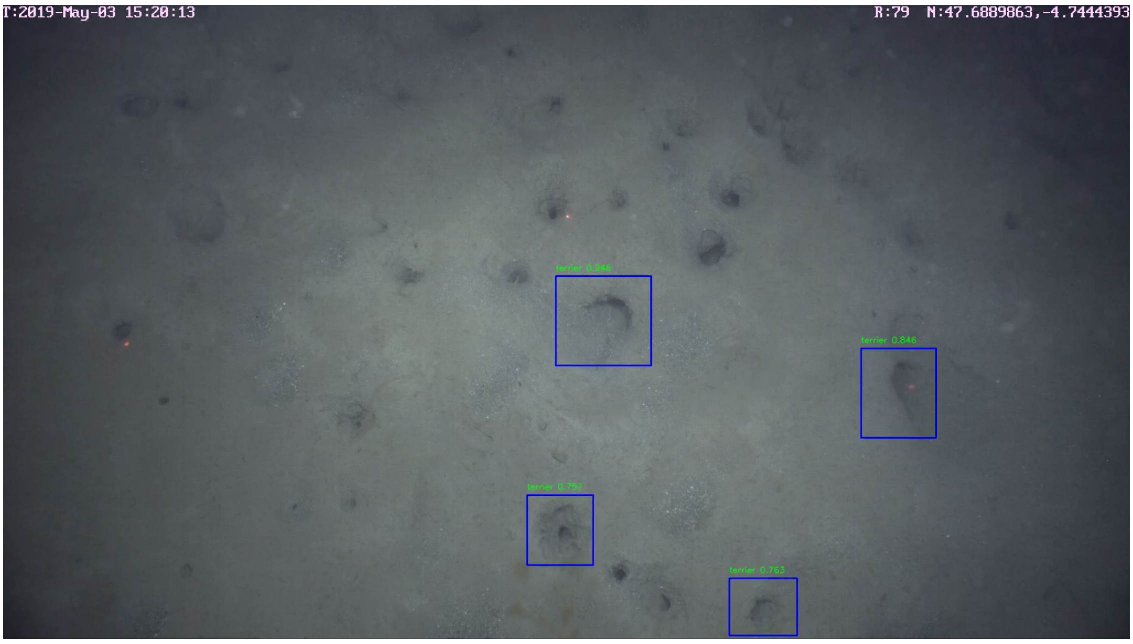


Figure 2. Still image from neural network programme.

Figure 3. Still image from neural network programme.

2.5 *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.

During the past many years *Nephrops* are counted manually (counting from TV surveys) from underwater videos which is very tedious and time-consuming task. These species are usually lived under the seabed and leaving behind some pattern of burrows. To identify this specie in underwater, one need to identify these patterns and judge the availability of *Nephrops*. The *Nephrops* burrows are very specific in their characteristics. Some of the major characteristics of burrows are:

1. At least one burrow opening is usually distinctly crescentic (half-moon) in shape. Where the angle of view permits sight of the tunnel beyond this opening, the angle of descent is usually shallow.
2. There is often evidence of expelled sediment, usually in a broad delta-like 'fan' at the burrow opening, and scrapes and tracks are often apparent.
3. *Nephrops* may be present (either in or out of burrow).

The objective of this research project is to develop a deep learning model to automatically detect, classify and count the *Nephrops* burrows. To achieve A deep learning based automatic system to detect, classify and count the *Nephrops* Burrow complexes will be developed.

The proposed work is using current state of the art Deep neural networks for objects detection and classification. To improve the detections the models, require some fine tuning and addition of more layers. In this work, the *Nephrops* surveys from Cadiz and Ireland are analyzed using Faster RCNN deep neural networks. The results show some good true positive detection from Cadiz and Ireland data.

2. Research Methodology

The system main objective is to develop an auto detection mechanism to classify and count the *Nephrops* burrows systems. Following are the main phases that are required to achieve the objective.

A. Data Preparation

a) Data Collection

The data used for experimentation and model training is from Cadiz and Ireland stations. The proposed deep learning model requires homogeneous data for training. The data collected from Cadiz is in the form of High Definition videos from the survey of 2018 and 2019.The duration of each video is 9-11 minutes. Each video is 25 frames per seconds. An individual video consists of 15000 frames on average. The data collected from Ireland is in the form of HD quality images. More than 1000 images were collected from Ireland. Table 1. Shows the raw dataset and its attributes.

Table 1: Dataset Attributes

Station	Year	Videos	Images
Cadiz	2018	100 minutes	150,000
Cadiz	2019	100 minutes	150,000
Ireland	2019	NA	1650

b) Data Cleaning

In the initial step all the images from Cadiz and Ireland were studied and removed if the lightening conditions and contrast of images are too bad to recover. Also, the repeated frames from the same video will not be considered in the dataset used for annotations. The available data require preprocessing due to its heterogeneous nature. The quality of videos will be improved by improving the lightening effects, noise mitigation, color compensation and image contrast enhancement.

c) Ground truth image annotations

The major step to prepare a good dataset is to annotate the *Nephrops* burrows. The ground truth annotations are the key for model training. To annotate the images, the Visual Object Tagging Tool (VOTT) from Microsoft has been used. VOTT helps in end to end machine learning pipeline. The tool allows to download the annotation in various format like csv, Jason, XML etc. From the Ireland dataset, out of 1650 images, 1133 images annotated and recorded 1699 annotations of *Nephrops* burrows in these images. From the Cadiz dataset only 266 images annotated and recorded 350 annotations.

d) Testing and Validation of annotations

Once all the ground truth annotations are recorded, now its time to validate the annotations before preparing the dataset for model training. The annotation validation is only possible from experts of *Nephrops*. Dr. Yolanda Vila from Cadiz helps in validating the ground truth annotations of Cadiz and Jennifer Doyle from Marine Institute of Ireland validated the ground truth annotations of Ireland.

e) Data preparation for Model Testing

The last step of this phase is to prepare the dataset for training the model. Table 2. Shows the annotated images of each station from Ireland and Cadiz that will be used in the model training and testing. Only 2018 survey of Cadiz is used in this dataset preparation. Total seven stations are annotated from Cadiz and recorded 266 annotated images. From Ireland survey, seven stations are annotated and recorded 1133 annotated images.

Table 2: Dataset Preparation

Cadiz Dataset		**Ireland Dataset**	
Station*	Annotations	Station	Annotations
RF01	42	Stn1	141
RF03	75	Stn10	201
RF04	34	Stn11	145
RF05	31	Stn15	179
RF07	13	Stn16	154
RF08	36	Stn26	155
RF09	35	Stn27	158
Total	**266**	**Total**	**1133**

B. Model Training

In model training phase, a deep neural model will be trained using the prepare dataset. Following are the steps required for training a model.

a) Dataset Format

Each annotated image has downloaded in an xml file which contains the information of image name, Class name (Nephrops), and bounding box detail of each annotation in the form of Xmin, Ymin, Xmax, Ymax. These Pascal VOC.

b) Dataset Distribution

To train a deep neural model, the data should be divided into train, validate and test. Table 3. Shows the distribution of this Cadiz and Ireland dataset.

Table 3: Dataset Distribution

Cadiz Dataset			Ireland Dataset		
Training Images	Validation Images	Testing Images	Training Images	Validation Images	Testing Images
200 (75%)	18 (7%)	48 (18%)	619 (55%)	155 (14%)	359 (31%)
Total Images = 266			**Total Images = 1133**		

c) Model Training

Faster RCNN is an object detection architecture presented by Ross Girshick, Shaoqing Ren, Kaiming He and Jian sun in 2015, and is one of the famous object detection architectures that uses convolution neural networks.

We trained more complex and denser model based on Faster RCNN, those are:

i. MobileNet v2
ii. Inception v2
iii. Resnet50
iv. Resnet101

d) Combination of Dataset for Training and Testing

With these complex models, we used combination of our available dataset from Cadiz and Ireland for training and testing.

To train the models following combination of datasets are used.

i. Cadiz Dataset
ii. Ireland Dataset
iii. Hybrid Dataset (Combination of Cadiz and Ireland)

Each model is trained with 70k iterations and precision are calculated on every 10k iteration. The tables from 4 to 7 shows the combination of training and testing dataset.

Table 4: Dataset for MobileNetV2

Combination of Dataset with MobileNetv2 Model				
Model	Training Dataset		Test Dataset	
	Station	Images	Station	Images
MobileNet	Cadiz	200	Cadiz	48
MobileNet	Ireland	618	Ireland	359
MobileNet	Cadiz	200	Ireland	150
MobileNet	Ireland	618	Cadiz	200
MobileNet	Hybrid	818	Hybrid	407
MobileNet	Hybrid	818	Cadiz	200
MobileNet	Hybrid	818	Ireland	359
MobileNet	Cadiz	200	Hybrid	96
MobileNet	Ireland	618	Hybrid	407

Table 5: Dataset for InceptionV2

Combination of Dataset with Inceptionv2 Model				
Model	Training Dataset		Test Dataset	
	Station	Images	Station	Images
Inception	Cadiz	200	Cadiz	48
Inception	Ireland	618	Ireland	359
Inception	Cadiz	200	Ireland	150
Inception	Ireland	618	Cadiz	200
Inception	Hybrid	818	Hybrid	407
Inception	Hybrid	818	Cadiz	200
Inception	Hybrid	818	Ireland	359

Table 6: Dataset for ResNet50

Combination of Dataset with ResNet50 Model				
Model	Training Dataset		Test Dataset	
	Station	Images	Station	Images
ResNet50	Cadiz	200	Cadiz	48
ResNet50	Ireland	618	Ireland	359
ResNet50	Cadiz	200	Ireland	150
ResNet50	Ireland	618	Cadiz	200
ResNet50	Hybrid	818	Hybrid	407

Table 7: Dataset for ResNet101

Combination of Dataset with ResNet101 Model				
Model	Training Dataset		Test Dataset	
	Station	Images	Station	Images
ResNet101	Cadiz	200	Cadiz	48
ResNet101	Ireland	618	Ireland	359
ResNet101	Cadiz	200	Ireland	150
ResNet101	Ireland	618	Cadiz	200
ResNet101	Hybrid	818	Hybrid	407

For each model used in our study, we performed certain number of experiments based on the combination of data we used. For every model used, at least nine different combination of dataset are applied. Each model is run with 70k iterations, so every model has in total 63 experiments performed. Table 8. shows the number of experiments performed for all the models.

Table 8: Total number of experiments performed.

Experiments Performed			
Model	Combinations	No of Iterations	No of Experiments
MobileNetv2	9	70k	63
Inceptionv2	9	70k	63
ResNet50	5	70k	35
ResNet101	5	70k	35
Total	**28**		**196**

C. Model Testing

a) Test Data

From Cadiz dataset 48 images are used in the testing of model and 359 images from Ireland dataset is used in the testing.

b) Quantitative Analysis

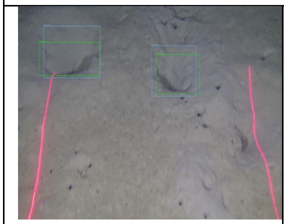
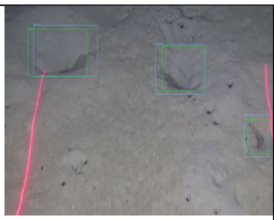
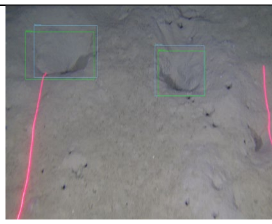
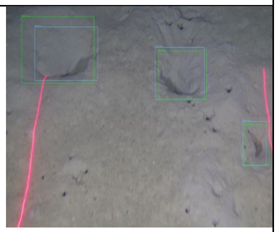
The Table 9. shows the performance evaluation of all the models used in the experimentation. The models are trained by Cadiz, Ireland and Hybrid dataset. While tested by all the combination of these dataset. A total of nine combination of experiments performed for each model to measure the performance evaluation in terms of mean Average Precision (mAP).

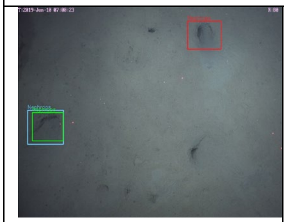
Table 9: Performance evaluation of Models

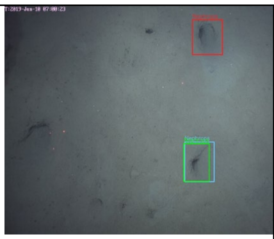
Models Performance Evaluation						
Training Dataset Station	Test Dataset Station	Models				Best Model
		MobileNet	Inception	ResNet50	ResNet101	
Cadiz	Cadiz	65.69	77.18	80.16	81.59	ResNet101
Ireland	Ireland	53.94	78.56	77.3	76.39	Inception
Cadiz	Ireland	50	47.86	39.06	41.04	MobileNet
Ireland	Cadiz	36.32	48.49	41.8	50.68	ResNet101
Hybrid	Hybrid	58.97	80.18	79.42	77.87	Inception
Hybrid	Cadiz	68.99	81.61	-	-	Inception
Hybrid	Ireland	56.45	79.99	-	-	Inception

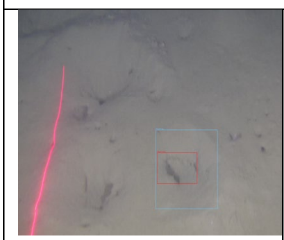
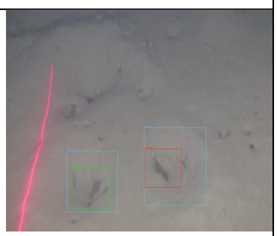
c) Qualitative Analysis

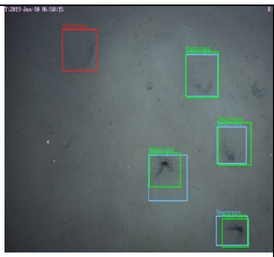
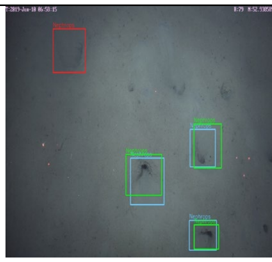
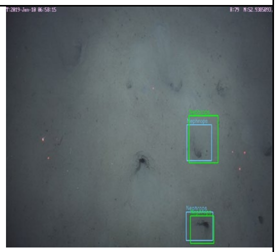
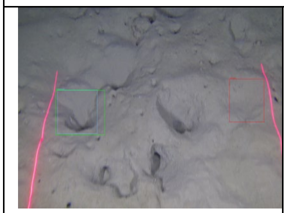
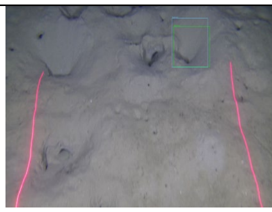
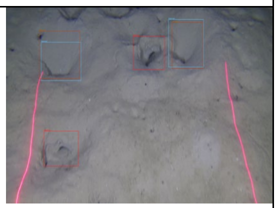
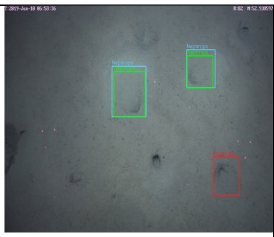
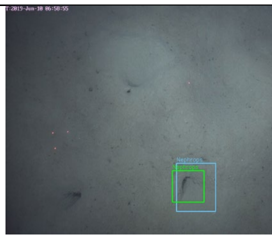
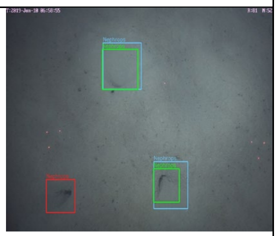
Here we compare the visual results of *Nephrops* burrows detection with all the models. The Inception and ResNet101 performs better in detecting more numbers of True Positive burrows. The figure below shows the detections of all the models.

Training Dataset: CADIZ → Test Dataset: CADIZ			
			
Mobilenet	Inception	Resnet50	ResnNet101

Training Dataset: IRELAND → Test Dataset: IRELAND			
			
Mobilenet	Inception	Resnet50	ResnNet101

Training Dataset: CADIZ → Test Dataset: IRELAND			
			
Mobilenet	Inception	Resnet50	ResnNet101

Training Dataset: IRELAND → Test Dataset: CADIZ			
			
Mobilenet	Inception	Resnet50	ResnNet101

Training Dataset: HYBRID ➔Test Dataset: HYBRID			
			
Mobilenet	Inception	Resnet50	ResnNet101
Training Dataset: HYBRID ➔Test Dataset: CADIZ			
			
Mobilenet	Inception	Resnet50	ResnNet101
Training Dataset: HYBRID ➔Test Dataset: IRELAND			
			
Mobilenet	Inception	Resnet50	ResnNet101

Conclusion

During the past many years *Nephrops* are counted manually (counting from TV surveys) from underwater videos which is very tedious and time-consuming task. These species are usually lived under the seabed and leaving behind some pattern of burrows. To identify this specie in underwater, one need to identify these patterns and judge the availability of *Nephrops*. In the current study, we get the data from Cadiz and Ireland stations, record the ground truth annotations from images. Based on the recorded annotation the data are divided into training, validation and testing dataset. We developed and trained deep neural models based on Faster RCNN MobileNet, Inception, resNet50 and ResNet100 for Cadiz and Ireland stations and get the results from trained models. The models are trained and tested by Cadiz, Ireland, and Hybrid dataset. The results are very promising but still need lot of improvement in the model.

In future the work will focus on improving the *Nephrops* detection accuracy by training the model using more complex neural network. Also, the model will be finetuned to handle the False positive and missing detections. The work will be required to classify the complete system of *Nephrops*. At the end a fully functional system will be developed to handle inputs from all the stations of different countries.

2.6 Reducing uncertainty & Assessing Bias in estimates of *Nephrops norvegicus* population *size (working paper).*

Niall G. Fallon, Stock Assessment and Modelling Group, Marine Scotland Science

Introduction

The fishery for *Nephrops norvegicus* is one of the most valuable in Scotland (£63m in 2018), representing ~11% of the value of all vessels' landings. The South Minch *Nephrops* Functional Unit (FU12), found off the northwest coast of Scotland (Figure. 1, *inset*) is assessed on an annual basis. The total abundance of *Nephrops* is estimated using burrow density data collected during a research vessel based underwater television survey (UWTV) (ICES, 2018). Estimates of stock size derived from UWTV survey sample data are subject to uncertainty arising from measurement error (i.e. sampling uncertainty). Minimising measurement error is essential to the calculation of survey quantities with a level of uncertainty which allows for the evaluation of trends in stock dynamics.

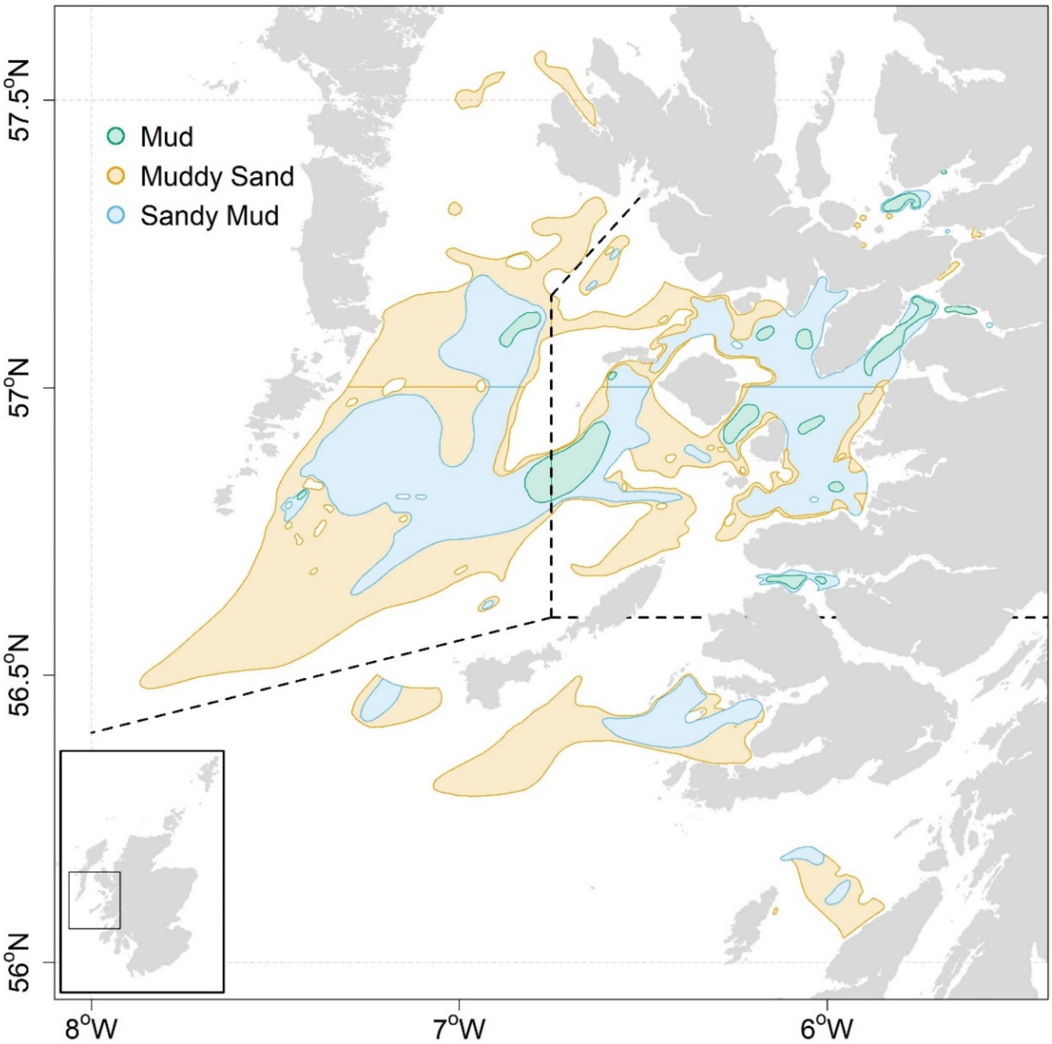


Figure 1. FU12 is divided into three areal strata (East, South, and West), and three sediment strata (Mud *green*, Sandy Mud *blue*, and Muddy sand *yellow*), for UWTV sample allocation purposes.

The current sampling scheme for FU12 is stratified across three sediment types (muddy sand, sandy mud and mud, following the Folk sediment classification) with fixed proportions of sampling effort in each of three areas (East, South and West; Figure. 1). Data from UWTV surveys of FU12 are characterised by relatively high sample variance due to substantial variability in burrow density within and between sediment types, when compared with the other *Nephrops* functional units off the West of Scotland. Estimates of abundance derived from FU12 survey data using the current method ("standard method", "standard abundance estimates"), a stratified mean estimator, therefore have relatively high uncertainty, affecting the precise detection of temporal trends in abundance. In addition, UWTV survey samples are not currently allocated in direct proportion to area in the case of two strata, Eastern Sandy Mud and Western Muddy Sand. Burrow counts in the Eastern Sandy Mud stratum are notable for being relatively high (between ~0.6 and 1 burrow per m^2), particularly in recent years, and thus their over-representation in the sample set may be problematic. Although the disparities in proportionate allocations are seemingly low (<10%), the sample allocation scheme could be introducing a bias to abundance estimates.

The aim of this study is to identify an abundance estimation method for FU12 *Nephrops* which has lower uncertainty when compared to the standard method, and to determine whether bias has been introduced to abundance estimates by the UWTV survey sample allocation method. Conditional Geostatistical Simulations (CGS) are used to generate estimates of *Nephrops* abundance which account for sampling error, and these estimates and uncertainty measures are compared to those derived using the standard method. In order to evaluate the bias (if any) in abundance estimates, a resampling routine is used to generate estimates based on the standard method, where samples are taken in direct proportion to the area of each survey stratum.

Methods

CGS were implemented in RGeostats (MINES ParisTech / ARMINES, 2020) to generate spatially explicit realisations of FU12 *Nephrops* burrow densities from based on UWTV survey data from 2006-2020 (*See* Petitgas *et al*. 2017 and Woillez *et al*., 2009 for a detailed description of the following methods). The first step in CGS involves characterising the spatial structure of the variable of interest (*Nephrops* burrow density) using variography (Rivoirard et al., 2000): i.e. the calculation and modelling of variability in density as a function of sample separation distance. Variogram models for each survey year were fitted as follows:

- Where density data contained zero values, data were transformed using an empirical Gaussian anamorphosis before calculation of experimental variograms on the truncated Gaussian-transformed variable. Haul densities with a value of zero were simulated in the Gaussian-transformed variable using a Gibbs sampler.

- Where density data did not contain zeros, the empirical Gaussian anamorphosis transformation was performed and the variograms were calculated from the resulting normal distribution.

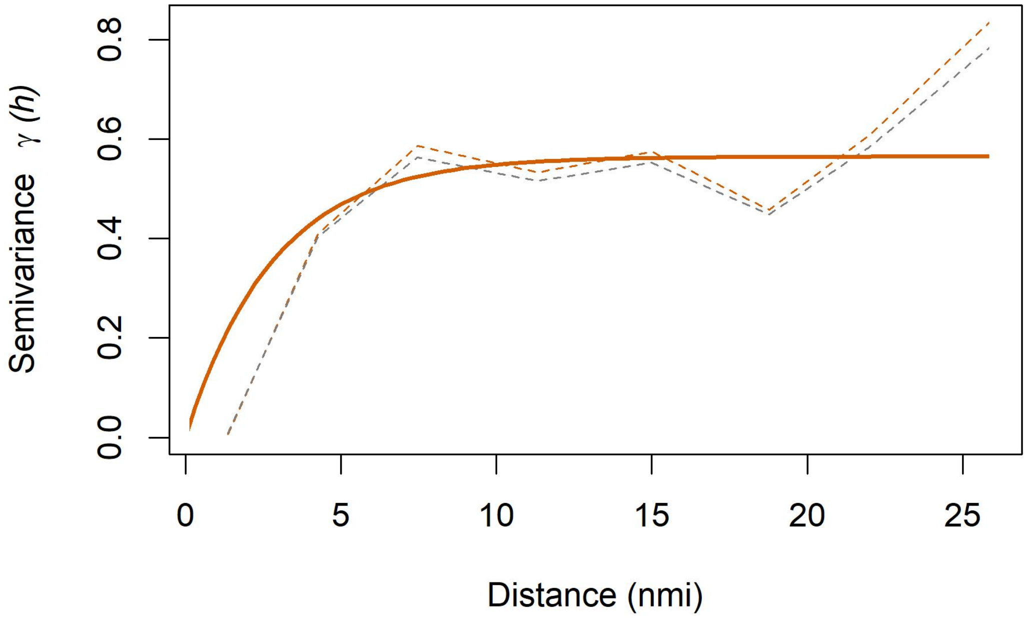


Figure 2. Variograms calculated for FU12 *Nephrops*, from 2011 UWTV survey data. The experimental variogram of the lower cut Gaussian variable is represented by the dashed grey line. The experimental variogram of the Gaussian variable, obtained using the Gibbs sampler, is represented by the dashed orange line. The model of the Gaussian variable is represented by the solid orange line.

Once an appropriate variogram model was obtained (e.g. Figure. 2), 500 realisations of burrow density across the main FU12 sediment patch were generated for each survey year using turning band simulations. The size of the grid onto which values are simulated is limited by the amount of available computer memory. Here, a grid size of 500 x 500 metres was used, the implicit assumption being that each survey sample (in burrows per m^2) was representative of the density across the associated grid square. The abundance of *Nephrops* across the remaining, smaller sediment patches (Figure. 3) was calculated using the standard method, and added as a scalar to the total abundance derived from each simulated realisation. An overall estimated mean abundance for each year could then be calculated from the resultant distribution of abundances, with confidence limits taken from the quantiles of the distribution, i.e. at 2.5% and 97.5%.

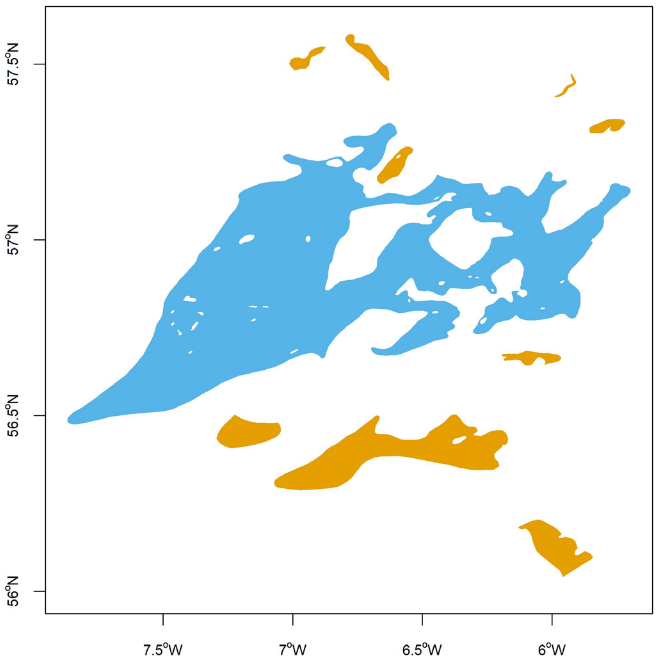


Figure 3. Sediment patches in FU12 used in the calculation of *Nephrops* abundance. The main (*blue*) patch is the area across which CGS was carried out. *Nephrops* abundance across the remaining (*orange*) smaller patches was calculated using the standard method, and a total abundance for each realisation was then summed across all sediment patches. The main sediment patch accounts for 82% of the survey domain by area.

In order to evaluate potential bias in UWTV survey abundance estimates, a resampling routine was implemented whereby a bootstrapped distribution of abundance estimates (n = 1000) was generated for each survey year using the standard method. Each estimate was derived based on a sample set which had a number of samples per stratum directly proportional to areal measurements.

Results

CGS realisations provide illustrative maps of the spatial distribution of *Nephrops* within the main sediment patch of FU12 (Figure. 4), where simulated burrow densities are conditioned to UWTV survey data; i.e. in each realisation the values on the simulated grids honour the burrow densities observed in the UWTV surveys.

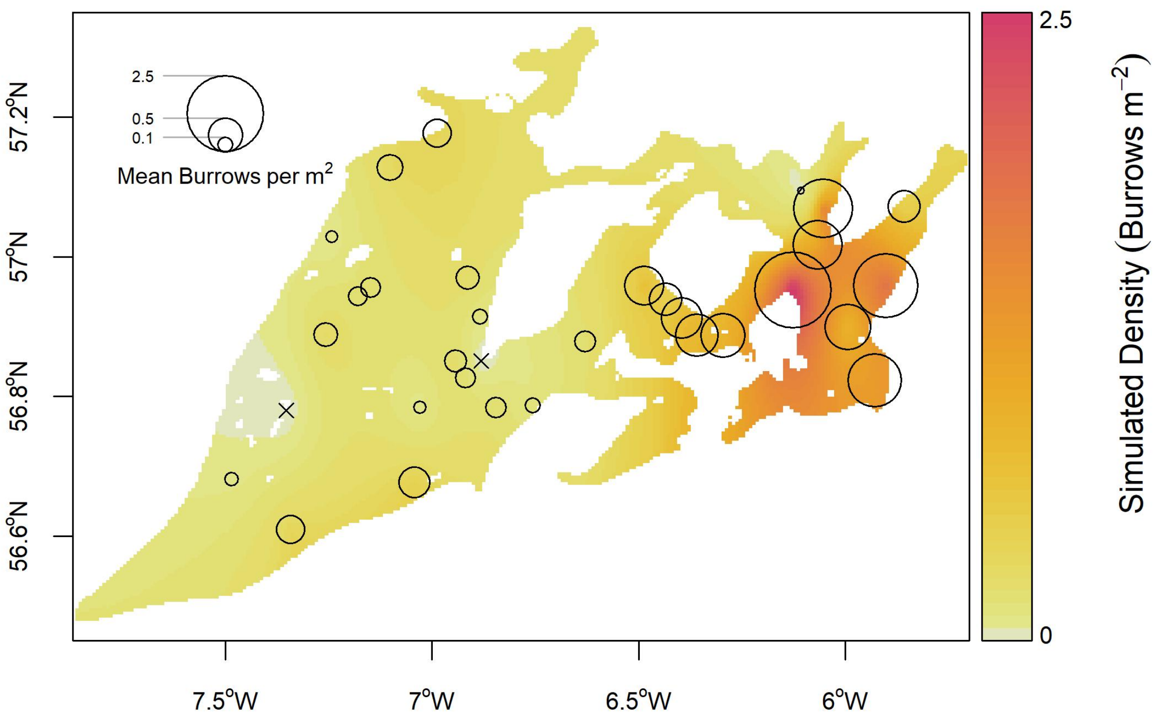


Figure 4. Mean Nephrops burrow density distribution for FU12, calculated across 500 CGS realisations using 2011 UWTV burrow density data (overlaid as a *black* bubble plot where bubble area is proportional to burrow density, the *black* x symbols represent zero density observations). Darker *red* pixels represent areas of higher Nephrops burrow density, and lighter *yellow* pixels represent areas of low density. Cream coloured pixels represent areas where burrows are absent.

Estimates of mean abundance derived using CGS were all lower than the estimates using the current method, apart from the 2016 estimate (Figure. 5), but the difference was only of borderline significance ($F_{(2, 42)} = 1.5$, $p = 0.09$). The resampling-based mean abundance estimates tended to be closer to (but were also generally lower than) standard estimates, and followed the same overall temporal trend. There was no significant difference between the resample-based estimates and those derived using the standard method ($F_{(2, 42)} = 1.5$, $p = 0.42$). Geostatistical abundance estimates, and their associated confidence limits were all within the uncertainty bounds of the standard abundance estimates, indicating that any deviations in temporal trend observed in the time-series of CGS estimates (e.g. slight difference between the two methods in trend from 2014 to 2016) were plausible in the context of the standard method, and the current understanding of the stock's dynamics, given the uncertainty around those estimates.

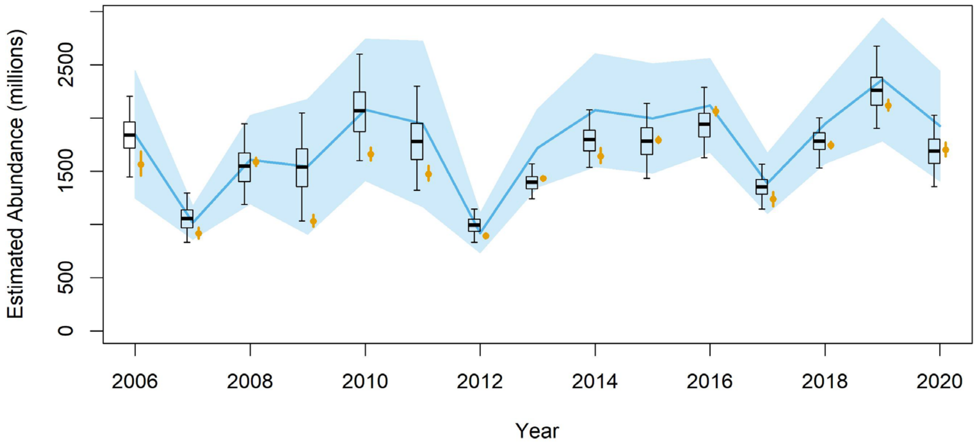


Figure 5. Time series estimates of FU12 *Nephrops* abundance with 95% CIs using the standard method (*blue line and polygon*) overlaid with geostatistical estimates of mean total abundance with 95% quantiles (*orange points and lines*), and resample estimates (*black boxplots*; the centre line is the mean, the whiskers are at the 95% quantiles of the bootstrap distribution).

Differences in magnitude aside, the three time series were highly correlated (pairwise Pearson correlation coefficients >0.88), suggesting generally good agreement between the trends observed across methods (Figure. 6).

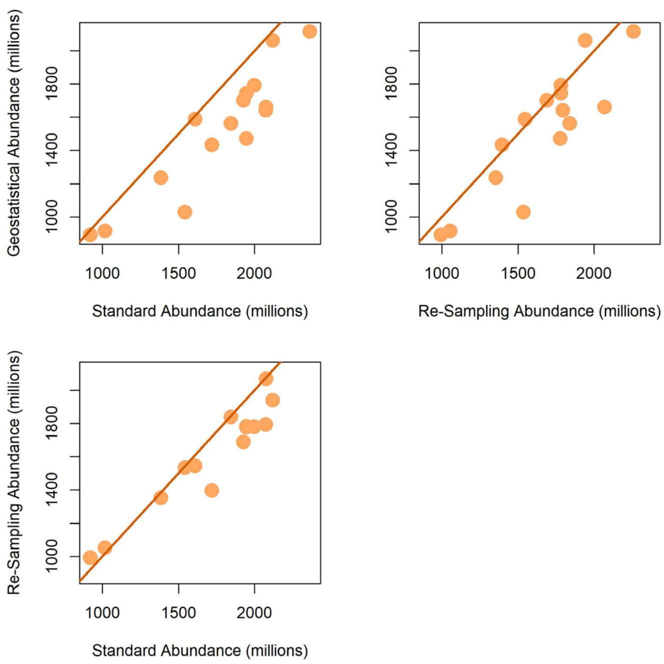


Figure 6. Pairwise comparisons of mean abundance estimates derived using CGS (Geostatistical abundance estimates), the resampling routine, and the standard method. Each plot panel includes a 1:1 line to aid in comparison of time series.

Compared to the standard method, there was a mean reduction in coefficient of variation of 87% using the CGS method (Figure. 7), suggesting that CGS may represent a viable abundance estimation approach for FU12 *Nephrops* with greatly decreased uncertainty compared to the standard method.

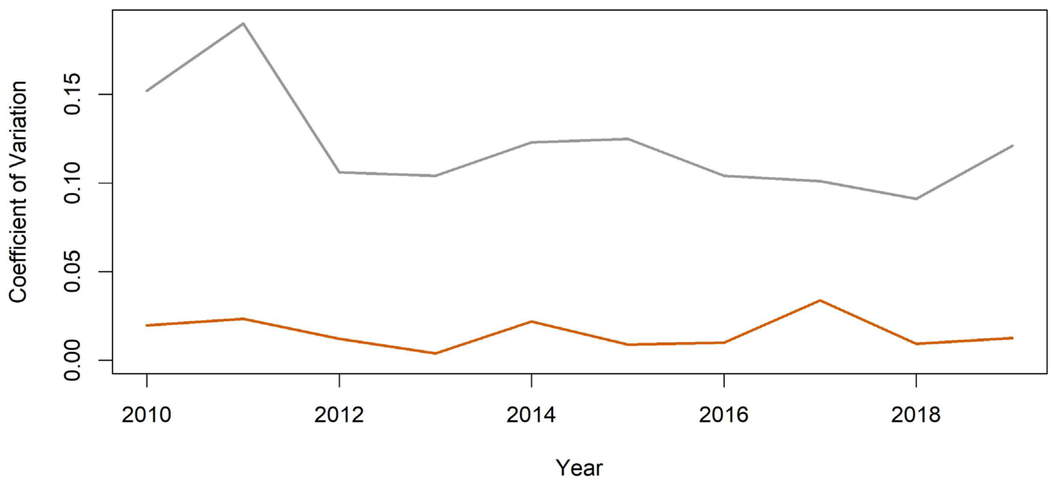


Figure 7. Time series of coefficients of variation for standard (grey line) and geostatistical (orange line) estimates of FU12 *Nephrops* abundance.

Discussion

CGS can provide estimates of *Nephrops* abundance for FU12, which have reduced uncertainty when compared to the standard method, while being of a comparable magnitude and following similar historical trends. As such, CGS may offer a solution to the long-standing issue of highly uncertain abundance estimates for that management area. Ultimately, the outcome of the method relies heavily on the ability to fit a useful variogram model. It is thus useful to fully explore the sensitivity of the variogram model fits to the assumptions applied in the calculation of the empirical variogram (e.g. distance lag). It may be useful to expand this analysis to multiple FUs to assess the performance of the CGS estimation method against the standard method in different scenarios.

Given the non-significant difference between the resampling-based method and the standard method, it does not appear that substantial bias has been introduced to the assessment due to the UWTV sample allocation method. Regardless, it would be favourable to correct the minor discrepancies in proportionate sample allocations for future surveys.

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2.7 A review of FU 30 survey area definition

Yolanda Vila and Candelaria Burgos

ISUNEPCA UWTV survey is carried out in the Gulf of Cadiz (UF 30) yearly in spring-summer since 2014, although the first survey is considered as exploratory. ISUNEPCA is a multi-disciplinary survey and different specific objectives are established:

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 by means of a CTD coupled to the sledge
5. To collect sediment samples
6. Seabed morphological and backscatter analysis

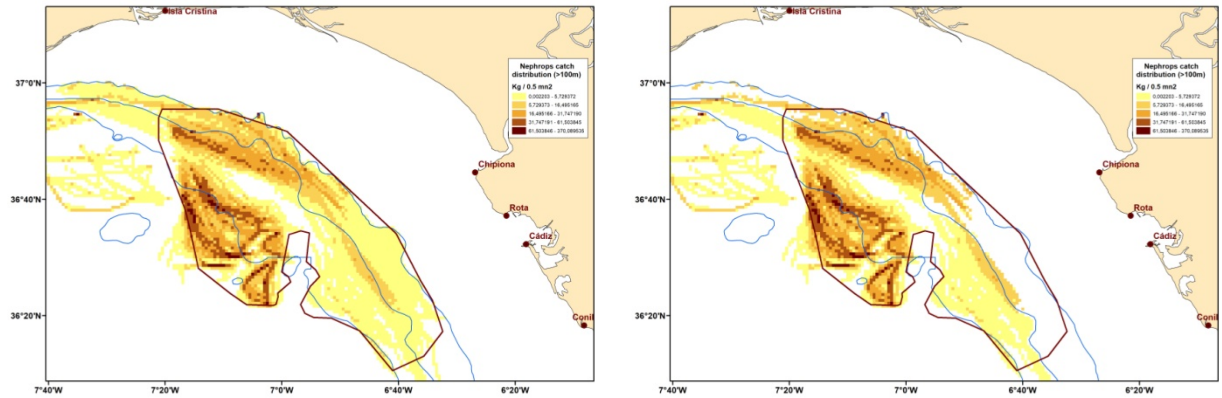
The design of the survey follows a randomized isometric grid at 4 nm spacing. Since 2016, stations are allocated in the grid in a rhomboidal way. A total of about 65-70 stations are yearly planned covering the Nephrops area distribution established in the last benchmarck (ICES, 2016). Footages have been recorded by a HD camera during the period 2015-2017 while a 4K UHD recording camera is used since 2018 (ICES, 2018). Unfortunately, ISUNEPCA UWTV survey could not be conducted in 2020 due the COVID-19 pandemic.

A review of the ISUNEPCA UWTV survey area has been carried out and presented during WGNEPS 2020. The current survey area used to obtain the Nephrops abundance estimate in the Gulf of Cadiz (FU30) was established mainly based on a combination of VMS and logbook data analysis (2011-2012) (ICES, 2016). Additional information as the Nephrops abundance from ARSA IBTS surveys (SP-GCGFS-Q1 and Q4) time series (1994-2014) and bathymetric and morphologic information (Díaz del Río et al., 2014; Vila et al., 2016) was also used. This area corresponds to 3000 Km2 and covers depths ranging between 90 m to 600 m, approximately. However, data compiled and the experience acquired during ISUNEPCA UWTV survey time series suggest that the shallowest limit and the Southern border could be different and, as a consequence, the survey area should be probably smaller than the current area. These facts could directly affect the Nephrops abundance estimate. Besides, visibility at those depths is very poor and the presence of other species with a burrowing behavior generates a high uncertainty in the Nephrops burrows identification. For that reason, the stations located in the shallowest limit of the area have been considered stations with zero Nephrops density in the last three years (ICES, 2017; 2018; 2020).

New and more accurate information is available now. One of them is the Andalusian monitoring system , called SLSEPA ("Sistema de Localización y Seguimiento de embarcaciones Pesqueras Andaluzas"), installed in most of fleets in the gulf of Cadiz, that transmit hour and positions (provided by (GPS), course and speed to the control centre every three minutes, (instead the two hours interval of European VMS) allowing for an accurate estimate of the actual fishing activity using a quite simple method not relying on strong assumptions. Additionally, updated data from ARSA IBTS survey time series (1993-2020) and beam trawl information obtained in the

ISUNEPCA UWTV survey during 2017-2019 periods, as well as recent habitat, sediment and the seabed morphology information (Lozano et al., 2019; Lozano et al., 2020) could be also very useful in order to redefine the survey area in FU 30.

Figure 1 shows the SLSEPA information linked to sales notes analysis in 2019 for the bottom trawl fleet in the Gulf of Cadiz (FU30). Landings data were apportioned to estimated fishing points for mapping the spatial distribution of the catch according to Gerritsen and Lordan (2010). Different filters were applied, as selecting records with speed value less or equal than 5 knots and deleting records located in shallow waters, less than 100 m deep where Nephrops is not targeted. The spatial distribution of the catches was estimated by summing the catch of points within 0.5 nm2 grid cells, a sufficient resolution based on the total size of study area.



a) b)

Figure 1. Analysis of Andalusian vessel monitoring system (SLSEPA) linked to sales notes from the bottom trawl fleet in 2019. a) Taking into account all vessels; b) Eliminating vessels than have not fish at more than 200 m deep in the same day with catches lower than 5Kg/day. Red polygon represents the current area used in ISUNEPCA UWTV surveys.

Most of the points located in 100-200 m stratum correspond to vessels that have also fished at more than 200 m deep the same day. Nevertheless, there are a proportion of vessels than only fish in shallower waters and have not fished in the deeper strata. So, a more detailed analysis of the 100-200 m stratum was carried out. Catches have been analyzed by ranges and it get have verified that in the shallower area in front of Cadiz bay, catches never exceeded 5 Kg/day, while higher catches correspond to vessels having fish also close to the 200 m isobaths. Vessels positions in the 100-200 m stratum with catches lower than 5Kg/day were excluded (Figure 1b).

The Nephrops abundance from ARSA IBTS surveys (SP-GCGFS-Q1 and Q4) time series indicates a very few quantities of Nephrops in that stratum (100-200 m), as well as in the Southern border of the current UWTV survey area, with only some exceptions during the time series (1993-2020) (Figure 2a).

The results obtained from the beam trawl hauls conducted during ISUNEPCA UWTV surveys in the 2017-2019 period showed presence of burrowing crustaceans as Goneplax rhomboids in the 100-200 m stratum but no individuals of Nephrops were caught in them (Figure 2b).

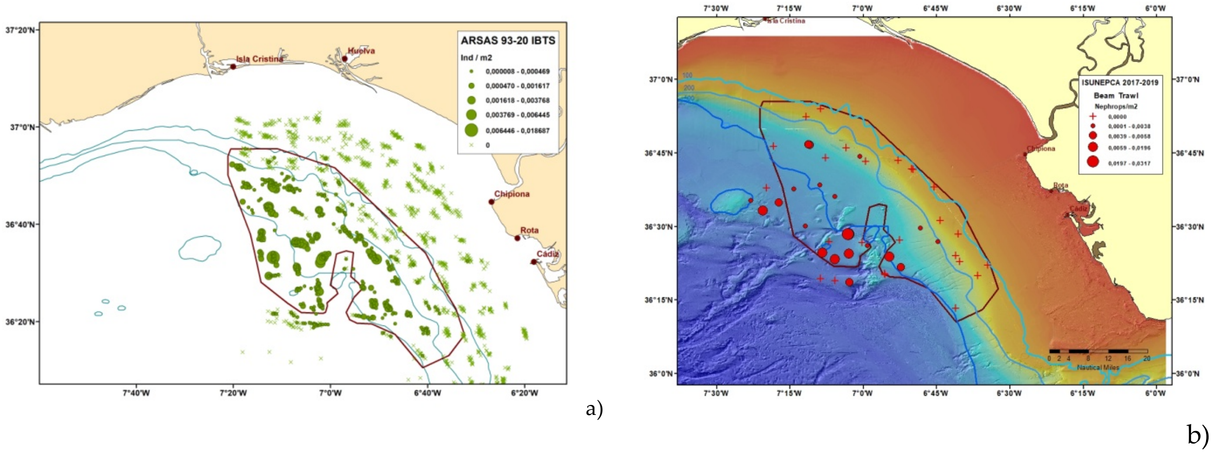


Figure 2. a) Nephrops abundance from ARSA IBTS surveys time series (1994-2020); b) Beam trawl hauls from ISUNEPCA UWTV surveys (2017-2019). The symbol + corresponds to zero Nephrops. Red polygon represents the current area used in ISUNEPCA UWTV surveys.

Different geological and oceanographic processes determine the distribution of a wide of geomorphological features, habitats and species in the Gulf of Cadiz. Channels, diapiric ridges and mud volcanoes can be found in the area (Figure 3) which harboring distinct benthic and demersal associated communities and habitats (Díaz del Río et al., 2014; Rueda et al., 2012). Some of them were taken account to establish the *Nephrops* distribution area used to ISUNEPCA UWTV survey in 2016 (Vila et al., 2016). However, more detailed seabed morphology information, as well as, new information about sediment and habitats in the Gulf of Cadiz are now available (Lozano et al., 2019; Lozano et al., 2020), which can be very useful for this issue.

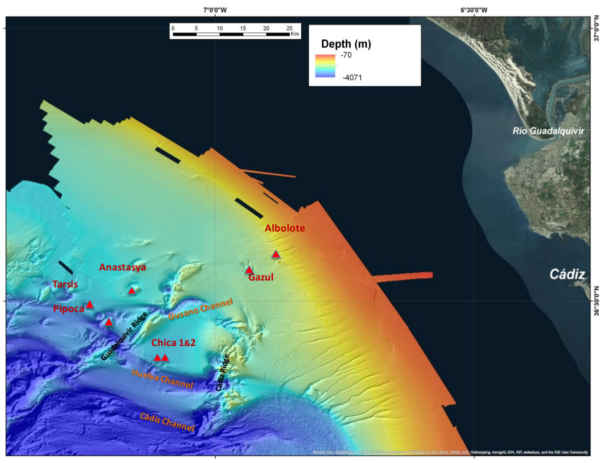
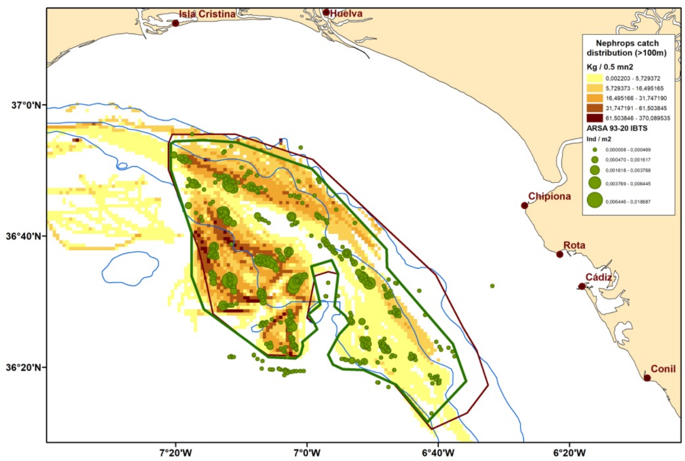


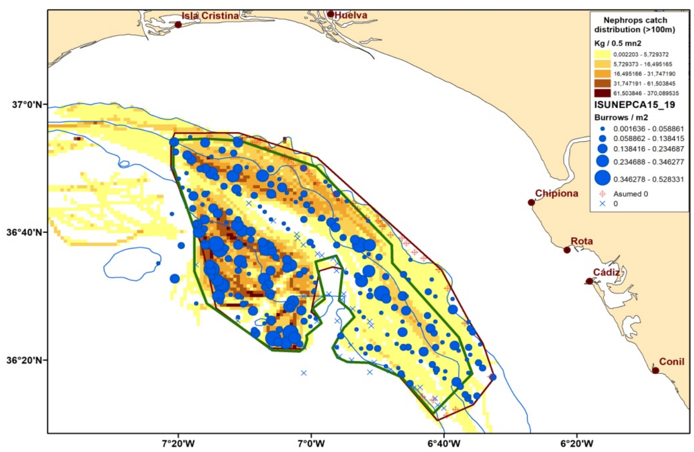
Figure 3. Main geomorphological seafloor features in the Gulf of Cadiz. Source: INDEMARES/CHICA Project (LIFE07/NAT/E/000732).

Figure 4a overlaps the results of SLSEPA analysis and *Nephrops* abundance from ARSA IBTS surveys, with the surrounding area (green line) and the current ISUNEPCA survey area (dark red line).

The geomorphic seafloor features have been taken account only in a rough way up the moment. Nevertheless, a more detailed redefinition of the area will be done in a near future, considering that information, as well as, the sediment composition and habitats results obtained by Lozano and collaborators in 2019 and 2020. On the other hand, some stations carried out during the ISUNEPCA UWTV survey time series, where *Nephrops* burrows systems were identified, would stay out of the new area proposed (Figure 4b). This survey is a relatively new, as it started in 2014. The low experience in the identification and quantification of the *Nephrops* burrows when the time series started could be the explication for the presence of *Nephrops* in this part of the area. For this reason, a review of the *Nephrops* density in those stations is needed in order to check them.



a)



b)

Figure 4. Preliminary (green polygon) and current (red polygon) ISUNEPCA UWTV survey area overlapped on the Andalucian vessel monitoring system (SLSEPE) linked to sales notes analysis from the bottom trawl fleet in 2019: a) Nephrops density from ARSA IBTS Survey time series (1993-2020) in green bubbles; b) Nephrops density from ISUNEPCA UWTV survey time series (2015-2019) in blue bubbles.

Conclusions and recommendations

1. Results obtained indicate that the ISUNEPCA UWTV survey area should be reduced, mainly in the shallowest and Southern border.
2. The survey area presented in this WG must only be considered as preliminary.

3. The *Nephrops* density in those stations staying out of the proposed area must be checked. In addition, the more detailed geomorphological seafloor features, sediment and habitat available information, should be taken into account.
4. The WGNEPS recommends finalizing this analysis before WGBIE, where a working document should be presented with the work conducted and the proposed new area for the ISUNEPCA UWTV survey. WGBIE should establish the procedure to follow in order to change the survey area in FU30.

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2.8 High definition reference sets

Mikel Aristegui, Marine Institute, Ireland

Since 2019, Irish UWTV surveys have been recorded in high definition camera. The digital format of the new footage allows remote analysis of the images in laptops and do not need any more CRT monitors and DVD players. This became a key feature in 2020, since COVID-19 restrictions did not allow the footage to be counted as usual onboard the Celtic Voyager. However, UWTV reference sets used by the Marine Institute (Ireland) until 2019 were recorded in DVDs using the previous UWTV standard definition camera. This means that counters would have not been able to be trained remotely before counting 2020 survey footage. Therefore, prior to the 2020 UWTV season, the Marine Institute decided to renew all their reference sets (FU16, FU17, FU2021 and FU22) using high definition footage from 2019 surveys.

In order to undertake such an important job, the Marine Institute followed the reference set compilation recommendations from WKNEPS (ICES 2018). The detailed procedure carried out for every Functional Unit's reference set is detailed below:

A) Selection of stations:
   1. Take all the UWTV 2019 survey stations.
   2. Split stations in *High*, *Moderate* and *Low* densities (tertiles).
   3. Sort each density group by Lin's CCC obtained by the 2019 pair of counters.
   4. By default: Choose the three highest Lin's CCC stations from each density group.
      But ensuring there is a variety of features among stations, such as:
      - Presence/absence of trawl marks.
      - Presence/absence of sea-pens.
      - Different ground types.
      - *Nephrops* in and out.
      - Some stations with low Lin's CCC.
   5. End up with 9 stations for the reference set.

B) Generate reference counts:
   1. Two experts involved: one expert running the annotation app (Aristegui 2020) and sharing the screen remotely with the second one.
   2. Open the station with the Annotation app in *SIC_matching* mode, which shows the annotations made by the 2 reviewers who counted the station back in 2019 (Figure 2.7.1).
   3. The two experts review together every single annotation made by those 2 reviewers, and confirm or reject each annotation.

Generating the reference counts was a time consuming task for the two scientists involved. The lowest density stations were reviewed in around 15 minutes, but more than one hour was needed for the highest density stations. The plan was to split each FU in three work sessions, aiming to review three stations in each session. However, a total of 14 sessions were needed for generating the four reference sets.

The final output of the full process was four HD reference sets (FU 16, FU 17, FU 20-21 and FU 22), each of them containing nine UWTV stations of eight minutes. The new reference sets do not only contain the count of burrows per minute (as standard definition sets used to contain), but also each burrow's annotation in the footage. Afterwards, training versions of the reference sets were created, including only annotations of the first two minutes of each station (or alternatively for very low density stations, annotations of the first few burrows of the station). The annotated reference sets are a highly valuable tool and will be key in future burrow identification training.

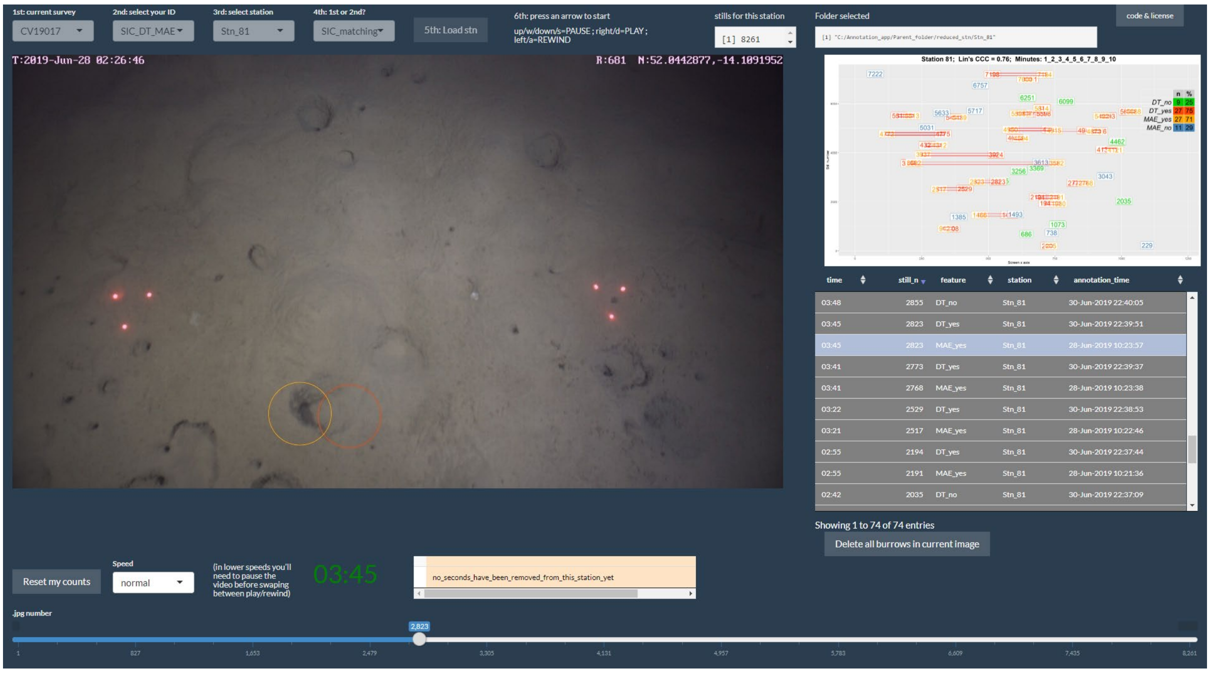

Figure 2.7.1. Marine Institute's annotation app example (Aristegui 2020). **Left**: UWTV high definition still image with a *Nephrops* burrow annotated by the two counters in 2019 (yellow and red circles). **Top-right**: summary of the station with a coloured map showing all the annotations from the two counters and a coloured table with the number and percentage of their matches. **Bottom-right**: clickable list of every single annotation, which allows instant visualization of each of them.

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3 Miscellaneous

3.1 GitHub update (ToR c)

ToR-c addresses the necessity to update R scripts for Nephrops UWTV survey data processing, including: functions to quality control, analyse and visualize data, and interface the tools with the international database for Nephrops UWTV survey data.

WGNEPS has updated the GitHub repository of the Working Group (https://github.com/ices-eg/wg_WGNEPS). The updated format of the repository works towards the standardisation of R scripts used currently by various institutes, and aims to support new developing surveys.

There are now four separated folders in the repository, each of them containing code for a different task related to UWTV surveys. All the folders include input files, R scripts and additional functions needed to run the code. This repository does not include output files, as stated in gitignore. However, output files could be uploaded in the future. The four main folders are:

A) Code for developing a reference set (WKNEPS 2018).
B) Code for running Lin's CCC test: pre-survey, training of Counters vs. Reference set counts.
C) Code for running Lin's CCC test: during survey, to compare Counters vs. Counters.
D) Code for plotting survey data.

Folder A) contains common code for all the institutes, as agreed in WKNEPS 2018. Folders B), C) and D) will contain individual folders for each institute, where all the international institutes are invited to share their code.

3.2 Other ToR’s

The WG reviewed the specifications for a Nephrops UWTV database to be established at the ICES data centre and agreed on further action on this issue and to hold intersessional meetings to progress this (ToR b; see Annex 5).

Work on The utility of Nephrops UWTV and Trawl surveys as platforms for collecting data for other purposes than the assessment of Nephrops stocks (ToR e) as well as on the analyses of factors affecting burrow emergence of Nephrops (ToR f) has been postponed.

An intersessional sub-group worked to address external reviewer comments on the UWTV survey protocols manual. This survey manual will now be transitioned as a TIMES publication and the process is underway (ToR a).

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Annex 2: Resolutions

The **Working Group on *Nephrops* Surveys** (WGNEPS), chaired by Jennifer Doyle, Ireland, will work on ToRs and produce deliverables and meet 16–18 November 2021 in Cadiz Spain to:

To review any changes to design, coverage and equipment for the various *Nephrops* UWTV and full-scale trawl surveys;

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

Updating R scripts for UWTV survey data processing including functions to QC, analyze and visualize data, and interface the tools with the database;

To review video enhancement, video mosaicking, automatic burrow detection and other new technological developments

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

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

Review differences of new HD and previous used SD camera systems and its effect on burrow detection, edge effects and bias correction factors, and explore the possibility of HD system tools for providing estimates of burrow size distributions.

WGNEPS will report by 1 February 2022 for the attention of the EOSG Committee.

Supporting information

Priority	*Nephrops* are a valuable species whose stocks are potentially sucseptible to local depletion. UWTV/Trawl surveys are an integral part of the stock assessment and management advice provided by ICES. WGNEPS is the international co-ordination group for *Nephrops* surveys focusing on planning, coloboration, quality control and survey development issues. This work is considered high priority.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 15–20 members and guests.
Secretariat facilities	ICES Data Centre
Financial	No financial implications.
Linkages to ACOM and group under ACOM	This group will feed into the assessment working groups and subsequently on to ACOM as well as to SCICOM
Linkages to other committees or groups	There is a very close working relationship with relevant to stock assessment experts groups that used the survey results i.e. WGCSE, WGBIE and WGNSSK and WGMLEARN.
Linkages to other organizations	FAO , OSPAR

Annex 3: Survey summaries

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 2012. The numbers of stations in FU 15, FU 17 and FU 22 were reduced since 2012 to allow for survey development in FU 16, FU 19 and FU 20-21 combined. The total numbers of stations for 2020 remains broadly similar ~300 to previous years (Figure 1). 100% coverage of all the Nephrops grounds was achieved in 2020 for stock assessment purposes.

Survey Design.

There were no changes to survey design for the surveys in 2020.

Survey Equipment.

Since 2019 HD camera system was used for all UWTV surveys.

Main results summary.

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 (ICES, 2012) for precision (Table 1). In 2020 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 UWTV Survey SISP (in draft) for FU 20-21 combined and FU 19 and a threshold of 0.6 for FU 16, FU 17 and FU 22 (Lin, 1989). All image data collected was in the high definition format in 2020 where HD stills for each station captured at 12 frames per second were reviewed using an in-house developed review app (Aristegui, 2020). Nephrops burrow systems were annotated for all grounds in 2020 using the review app. Figure 2 shows app GUI with annotated burrow in the image.

The adjusted mean density for each station in ICES Subarea 7 is presented in Figure 3 and it shows the general overall pattern which is mainly higher densities observed in FU15 western Irish Sea and lower densities in FU16 Porcupine Bank. There was an overall decrease in observed burrow densities in the Celtic Sea in 2020 compared to last year.

International staff exchange.

Due to the COVID-19 situation there was no international staff exchange onboard Marine Institute surveys in ICES Subarea 7 in 2020.

Image Data counting and reviews.

Due to COVID-19 situation survey operations in 2020 with reduced personnel were limited to data acquisition and quality control of image and navigation data only. All counting reviews were completed by the counting teams in home offices post surveys using the review app and MS Teams platform for training and discussion. Counting teams comprised of a minimum of 4 to a maximum of 6 individuals.

Data Storage and R-scripts.

All UWTV survey data for the entire time series is housed in a SQL server database. The r-scripts for data quality control and calculations of abundance estimations using geo-statistical analyses for FU 16, FU 17, FU 20-21 combined and FU 22 and also random stratified work up for FU 19 are available in r markdown documents for transparency and reproducibility.

Data Management Quality Management Framework.

In February 2019, the Marine Institute received the international accreditation of its Data Management Quality Management Framework (DM-QMF) by the (UNESCO) International Oceanographic Commissions (IODE) - International Oceanographic Data and Information Exchange programme. The overall aim of the DM-QMF is to support continual improvement of the quality of the data, products and services delivered by the Marine Institute through assuring the quality of the processes and procedures used in the generation of data and products. Marine Institute Nephrops UWTV survey data and products are included in this framework since 2019. Three Nephrops UWTV survey datasets are now available in the Marine Institute Data Catalogue. Table 1 shows the available UWTV datasets and links to these.

UWTV survey reports availability.

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

Additional Sampling:

Comparison TV tracks.

Comparison UWTV tracks with both High Definition and Standard camera systems were carried out at FU 17, 22 and FU 20-21 combined using a random selection of 15% of stations per FU. Both cameras were mounted on the same sledge used in previous UWTV surveys: the SD camera was set up as in previous surveys at an angle of 40° to the seabed, while the HD camera was set up at an angle of 75°. The SD image data has not been reviewed in 2020.

Sediment Sampling.

In 2020 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. The processed data will be used to generate sediment maps for this area and also to ground truth any seabed mapping programmes (www.infomar.ie).

Also sediment samples were retrieved at each Nephrops Functional Unit as part of a microplastics project by the Galway-Mayo Institute of Technology (GMIT).

Bottom Temperature and Depth data.

In 2020 this sensor was not operational.

Beam Trawling Operations.

Due to time constraints in 2020 beam trawl fishing operations were not carried out on the Aran Nephrops grounds (FU 17) and the Smalls Nephrops grounds (FU 22).

Other Benthic fauna distributions.

Monitoring the occurrence and frequency of other sea-pens observed on Nephrops grounds is important but is dependent on national resources. An OSPAR special request to record sea pens species (Virgularia mirabilis, Funiculina quadrangularis and Pennatula phosphorea) using a key devised to categorise the density (ICES, 2011) exists. In 2020 presence/absence of these three species was recorded in FU 16, 17, 19, 20-21 and 22. Figure 4 shows the 2020 stations on the Porcupine Nephrops grounds where the aforementioned sea-pen species were identified and noted as present or absent. The deep water sea-pen Kophobelemnon stelliferum has been observed during the UWTV survey on the Porcupine Banks (FU 16) Nephrops ground. It is an easy species to identify from the image data due to its specific shape and colour.

Seapen presence/absence data from the FU 16 Porcupine UWTV survey was provided as part of a 2020 datacall for new information on Vulnerable Marine Ecosystems (VME) in the North Atlantic for the Joint ICES/NAFO Working Group on Deep-water Ecology (ICES, 2020).

Table 1. *Nephrops* UWTV survey datasets currently available on the Marine Institute Data Catalogue.

***Nephrops* UWTV Survey Dataset**	**Marine Data Catalogue Link**
FU 22	https://tinyurl.com/yxo6ltnh
FU 20-21 combined	https://tinyurl.com/y3yfgzq9
FU 16	https://tinyurl.com/y2s6pbgx

Table 2. 2020 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 of individuals)**	**CV (Relative standard error)**	**Lin's Concordance Correlation Coefficient Threshold to screen survey Counts**
FU 16	0.17	1264	4%	0.6
FU 17 Aran Grounds only	0.29	359	4%	0.6
FU 19	0.16	320	15%	0.5
FU 20-21 combined	0.102	1020	5%	0.5
FU 22	0.27	750	8%	0.6

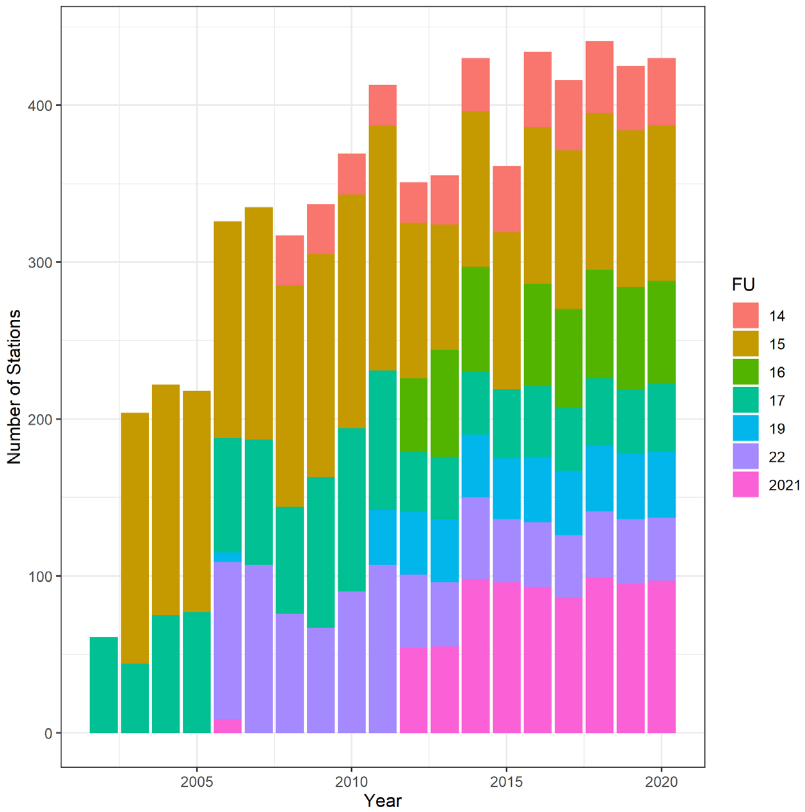

Figure 1. Time series of the total number of UWTV stations carried out by Ireland in each Functional Unit. Stations in FU 14 and FU 15 are carried out in collaboration with AFBI in UK-NI and CEFAS UK E&W.

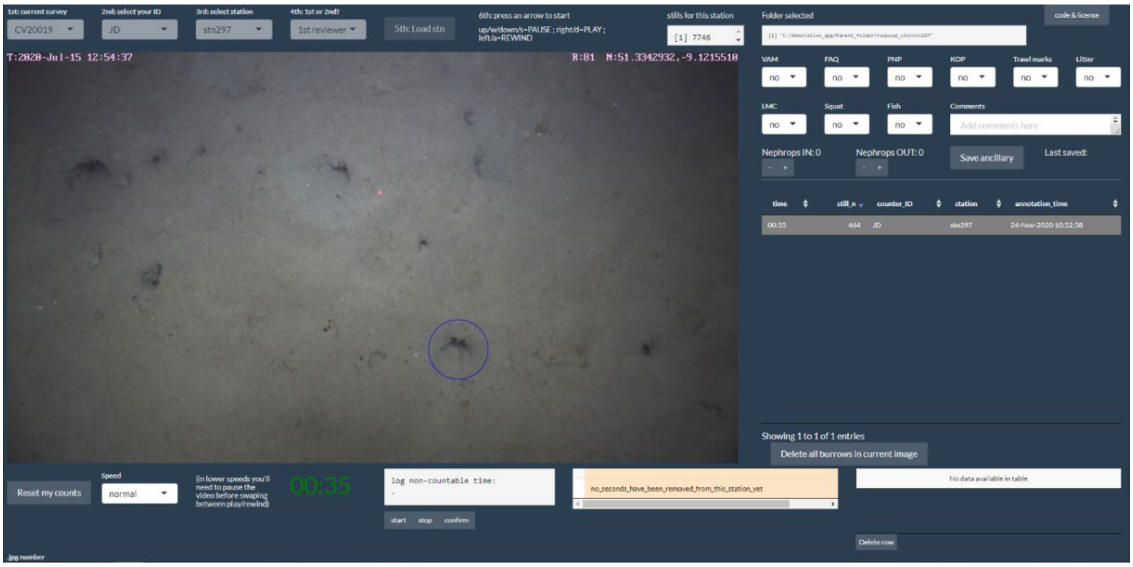

Figure 2. Screenshot of the Image annotation R shiny app used to annotate UWTV footage during the 2020 surveys. Blue circle denotes annotated burrow system.

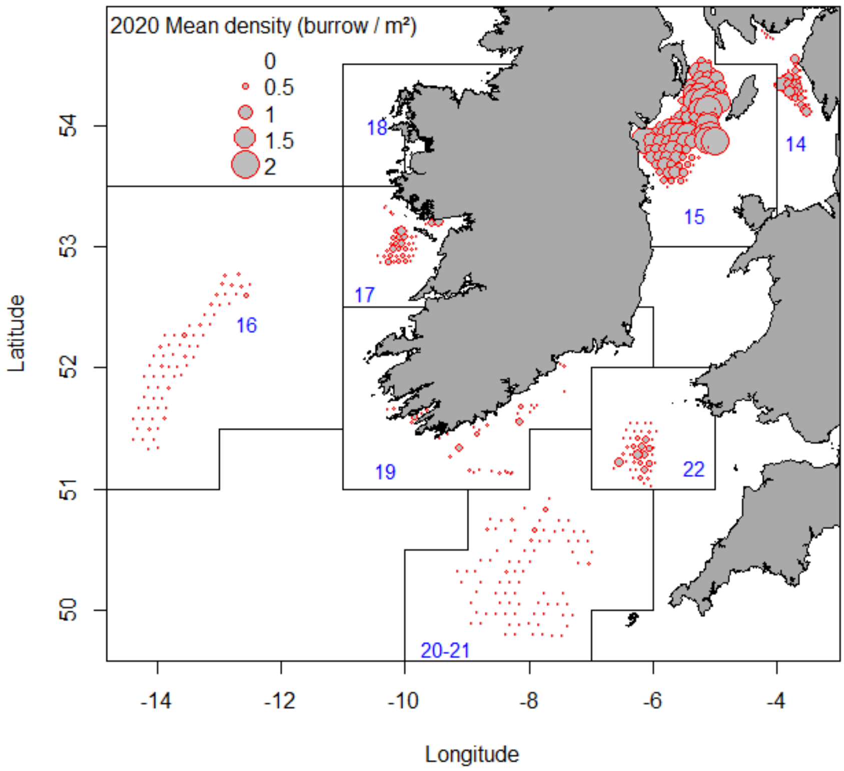

Figure 3. 2020 Mean adjusted density estimates (burrow/m²) by station for *Nephrops* grounds in ICES Subarea 7.

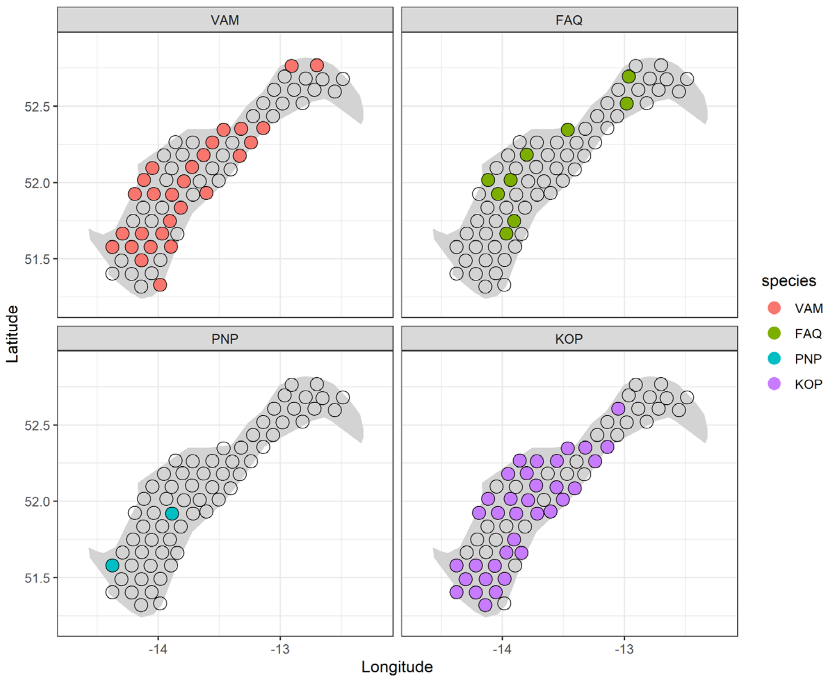

Figure 4. FU16 grounds: 2020 stations where *Virgularia mirabilis* (VAM), *Funiculina quadrangularis* (FAQ), P*ennatula phosphorea* (PNP) and *Kophobelemnon stelliferum* (KOP) were identified and noted as present or absent. Closed circles indicated presence and open circles denotes TV stations with no sea-pen observations.

UWTV Survey FU16: Porcupine Banks.

The 2020 survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. In total 65 UWTV stations were successfully completed in a randomised 6 nautical mile isometric grid covering the full spatial extent of the stock. The mean burrow density observed in 2020, adjusted for edge effect, was 0.17 burrows/m². The final krigged abundance estimate was 1264 million burrows with a CV of 4% and an estimated stock area of 7,130 km². The 2020 abundance estimate was 25% higher than in 2019. Using the 2020 estimate of abundance and updated stock data implies catches between 2653 and 3290 tonnes in 2021 that correspond to the F ranges in the EU multiannual plan for Western Waters (assuming that all catch is landed). Four species of sea-pen; *Virgularia mirabilis*, *Funiculina quadrangularis*, *Pennatula phosphorea* and the deepwater sea-pen *Kophobelemnon stelliferum* were observed during the survey. Trawl marks were also observed on 22% of the stations surveyed.

Further details on this survey available at: http://hdl.handle.net/10793/1655

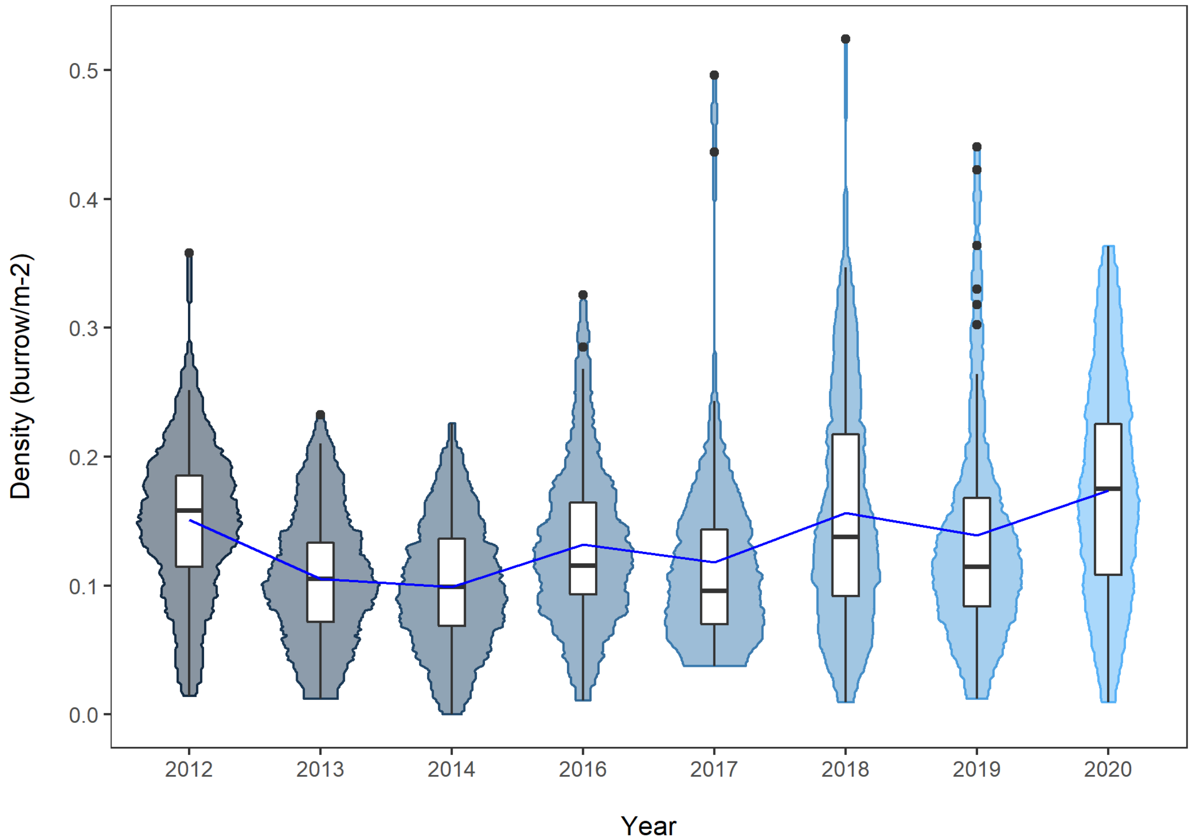

Figure 5. FU 16 Porcupine Bank: Violin and box plot of adjusted burrow density distributions by year for the available time series 2012 to 2020. No UWTV survey in 2015. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

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

In 2020 the nineteenth 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 multi-disciplinary in nature collecting UWTV and other ecosystem data. In 2020 a total of 44 UWTV stations were successfully completed, 34 on the Aran Grounds, 5 on Galway

Bay and 5 on Slyne Head patches. The mean burrow density observed in 2020, adjusted for edge effect, was medium at 0.29 burrows/m². The final krigged burrow abundance estimate for the Aran Grounds was 359 million burrows with a CV (Coefficient of Variance; relative standard error) of 4%. The final abundance estimate for Galway Bay was 27 million and for Slyne Head was 7 million, with CVs of 13% and 4% respectively. The total abundance estimates have fluctuated considerably over the time series. The 2020 combined abundance estimate (394 million burrows) is 20% lower than in 2019, and it is below the MSY $B_{trigger}$ reference point (540 million burrows). Using the 2020 estimate of abundance and updated stock data implies catches between 443 and 508 tonnes in 2021 that correspond to the F ranges in the EU multi annual plan for Western Waters, assuming that discard rates and fishery selection patterns do not change from the average of 2017–2019. *Virgularia mirabilis* was the only sea-pen species observed on the UWTV footage. Trawl marks were present at 7% of the Aran stations surveyed. Further details on this survey available at: http://hdl.handle.net/10793/1656

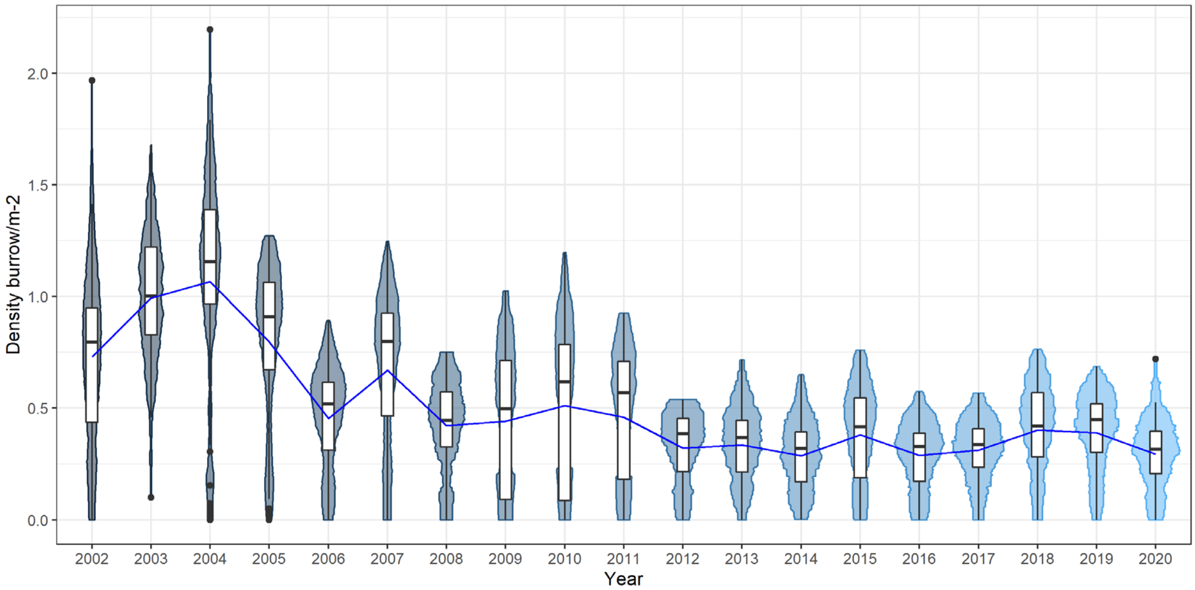

Figure 6. FU17 Aran grounds: Violin and box plot of adjusted burrow density distributions by year from 2002-2020. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

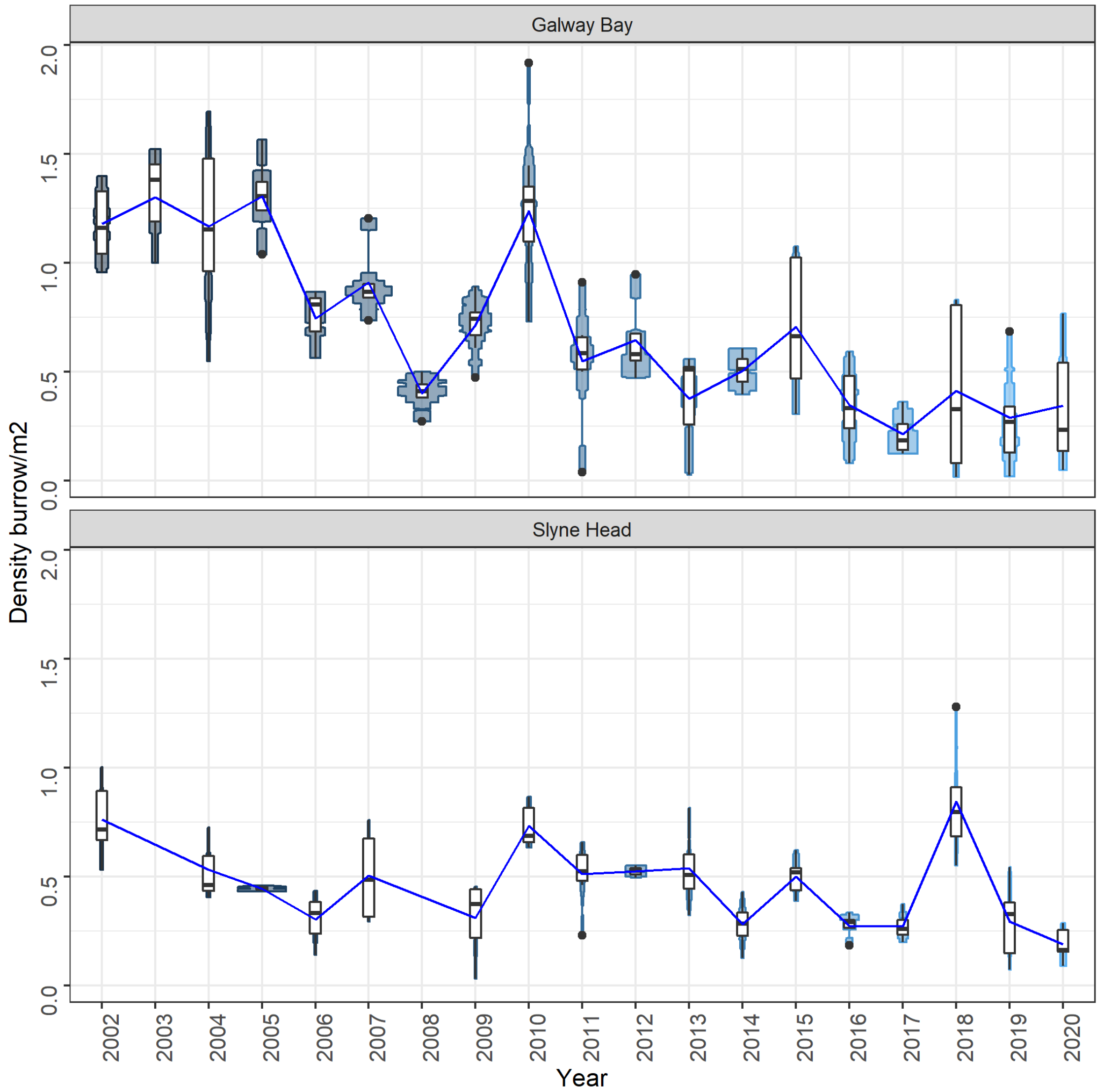

Figure 7. FU17 Galway Bay and Slyne Head: Violin and box plot of adjusted burrow density distributions by year from 2002-2020. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

UWTV Survey FU19. South and South west coast of Ireland.

The survey was multi-disciplinary in nature collecting UWTV other ecosystem data. In 2020 a total 42 UWTV stations were successfully completed. The mean density estimates varied considerably across the different patches. The 2020 raised abundance estimate was a 20% decrease from the 2019 estimate and at 320 million burrows is below the MSY $B_{trigger}$ reference point (430 million). Using the 2020 estimate of abundance and updated stock data implies catch in 2021 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 531 and 595 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2017–2019). Two species of sea pen were observed; *Virgularia mirabilis* and *Pennatula phosphorea* which have been observed on previous surveys of FU19. Trawl marks were observed at 26% of the stations surveyed.

Further details on this survey available at: http://hdl.handle.net/10793/1654

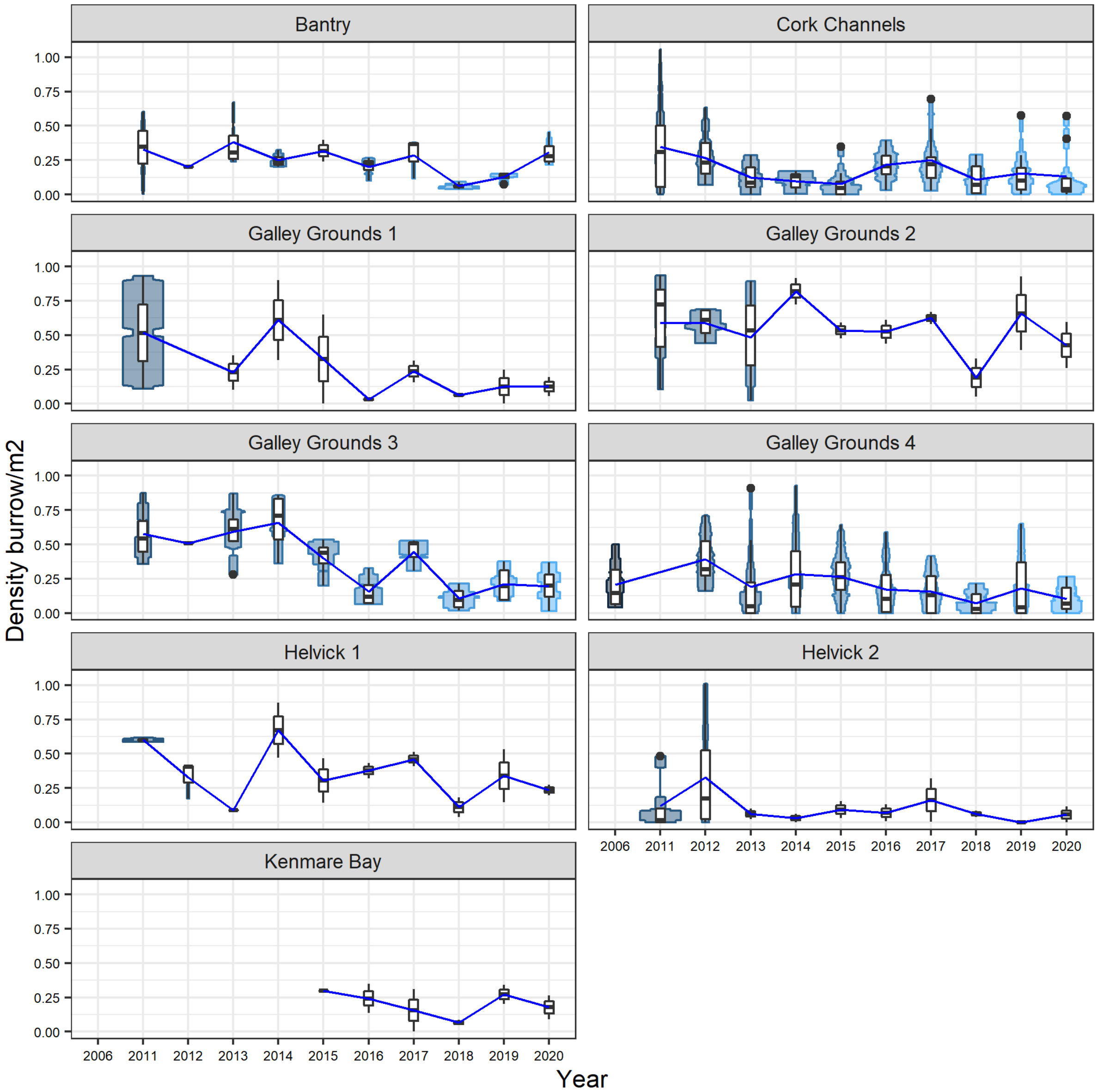

Figure 8. FU19 grounds: Violin and box plots of adjusted burrow density distributions by year for 2006-2020 for each ground. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No TV survey from 2007 – 2010.

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

The 2020 survey achieved full coverage of the stock area for the seventh 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 2020 survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. A total of 97 UWTV stations were completed at 6nm intervals over a randomised isometric grid design. The mean burrow density was 0.102 burrows/m2 compared with 0.06 burrows/m2 in 2019. The 2020 geostatistical abundance estimate was 1020 million, a 65% increase on the abundance from 2019, with a CV of 5%, which is well below the upper limit of 20% recommended by SGNEPS 2012. Low to medium densities were observed throughout the ground. Using the 2020 estimate of abundance and updated stock data implies catch in 2021 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 1682 and 1710 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2017–2019). One species of sea-pen (*Virgularia mirabilis*) were recorded as present at the stations surveyed. Trawl marks were observed at 36% of the stations surveyed.

Further details on this survey available at: http://hdl.handle.net/10793/1657

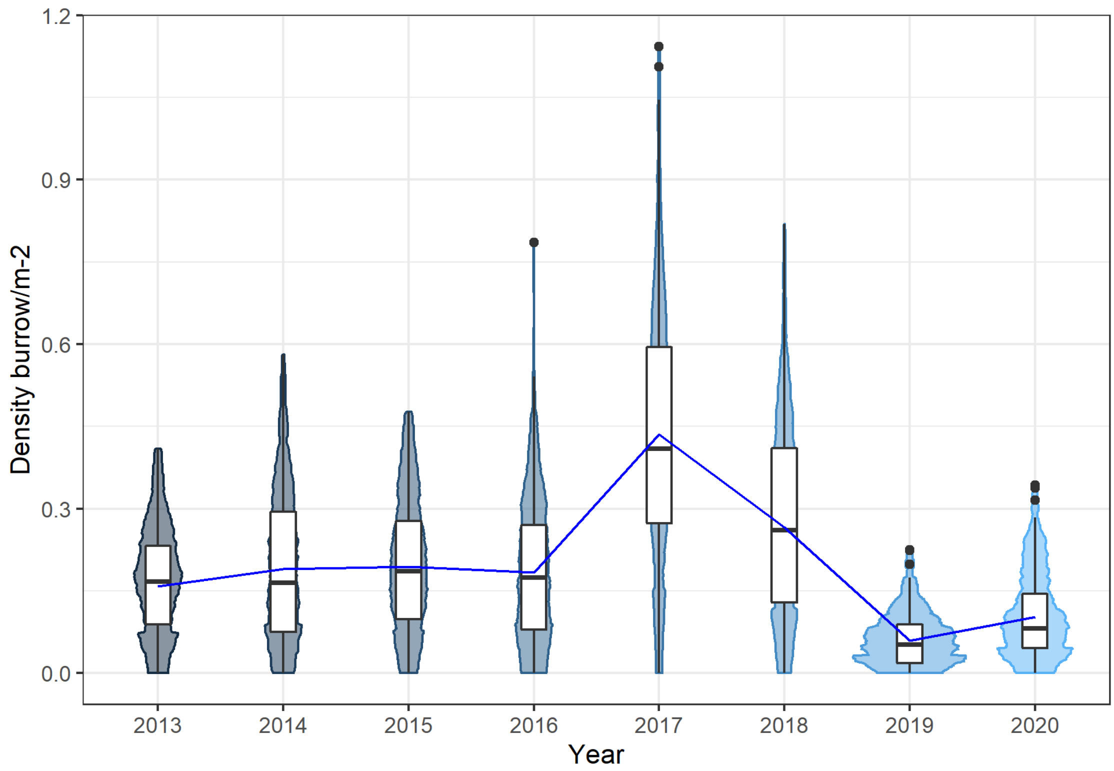

Figure 9. FU20-21 grounds: Violin and box plot of adjusted burrow density distributions by year from 2013-2020. The blue line indicates the mean density over time. The horizontal blacks line represents medians, white boxes the inter quartile ranges, the black vertical lines are the range and the black dots are outliers.

UWTV Survey FU22: The Smalls.

The 2020 survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. A total of 40 UWTV stations were surveyed successfully (high quality image data), carried out over an isometric grid at 4.5nmi or 8.3km intervals. The precision, with a CV of 8%, was well below the upper limit of 20% recommended by SGNEPS (ICES, 2012). The 2020 abundance estimate was 33% lower than in 2019 and at 750 million is below the MSY Btrigger reference point (990 million). Using the 2020 estimate of abundance and updated stock data implies catch in 2021 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 1238 and 1560 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2017–2019). One species of sea pens was recorded as present at the stations surveyed: *Virgularia mirabilis*. Trawl marks were observed at 48% of the stations surveyed.

Further details on this survey available at: http://hdl.handle.net/10793/1658

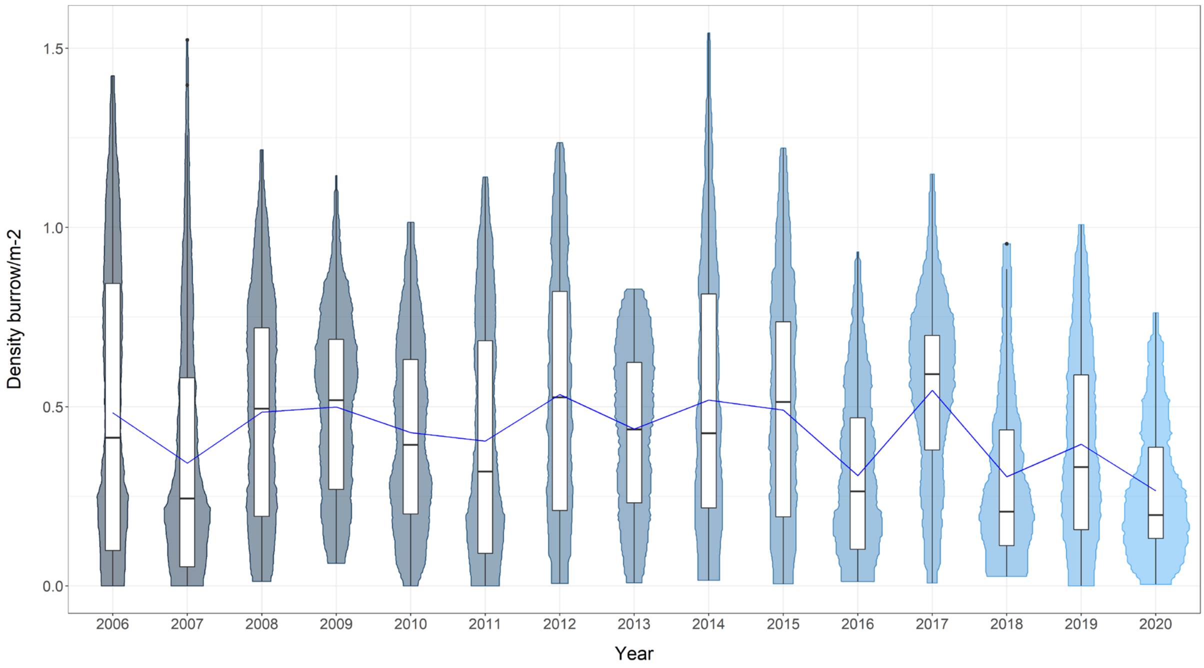

Figure 10. FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006-2020. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers.

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UK Northern Ireland FU 15

(Mathieu Lundy)

Functional Unit	FU 15	Area name	Western Irish Sea
Survey design	Random grid	Previous surveys	2003-2019
Country (ies)	UK & Ireland	Vessel name (s)	R/V Corystes
Survey code (s)	CO3120	Dates (start/end)	6th – 12th Aug 2020
Number scientific staff	5	Staff exchanges	N/A
Number of stations (planned/completed/used in analysis)		100/99/99	
Deviations from the survey plan (e.g. coverage/weather related problems, technical problems, potential biases, etc.)		No deviations. Ship position used for distance over ground as in 2019	
Distance over ground source used	Ship	Average field of view (cm)	Analogue cam: 68 cm
Adjusted mean density	0.82	Adjusted abundance, CV	4872 million, CV=2.91%
Overall footage quality (poor, medium, good)		Medium	
Reference footage for survey area generated		Yes	
Quality control of station counts (Lin's CCC or consensus count) State Lin's CCC threshold		Lin's CCC threshold 0.5	
Other survey activities (CTD, Trawl, sediment samples, sediment profile images, % stations with trawl marks recorded, presence/absence sea-pen distribution etc.)		CTD Beam trawl hauls *Nephrops* otter trawls	
Data storage, level of analysis and dissemination (by data type)		Nephrops burrow counts	9706 Nephrops burrows counted, **storage**: DVD up to 2020, **level of analysis**: kriged estimates as for last year **dissemination**: WGCSE
		CTD	99
		Trawl	48
		Sediment	0
		Other	0

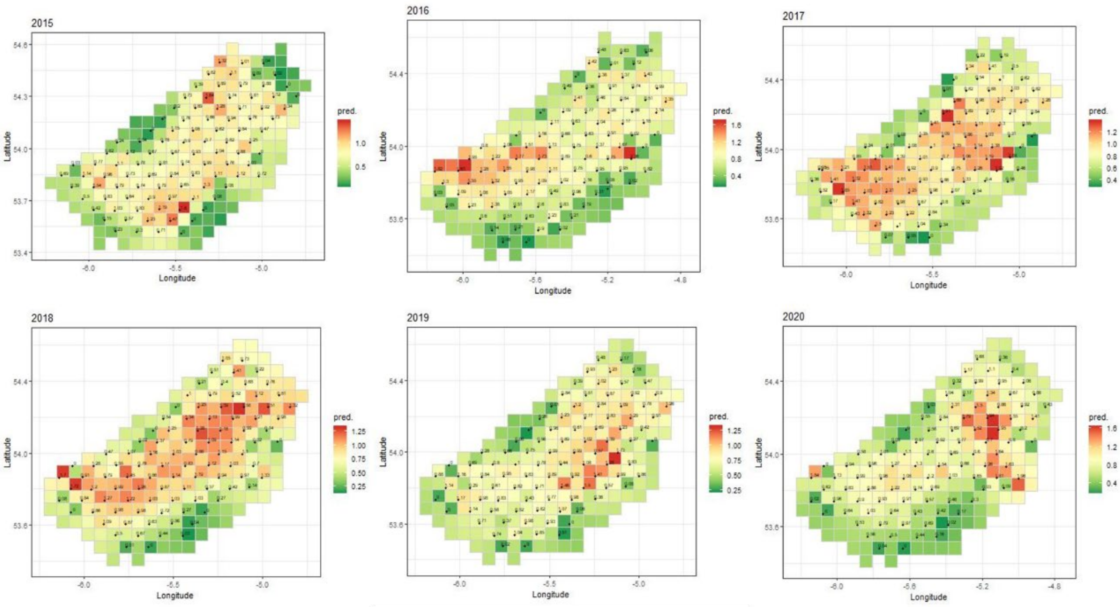

Figure. 1: Map of kriged density by station for 2015 – 2020.

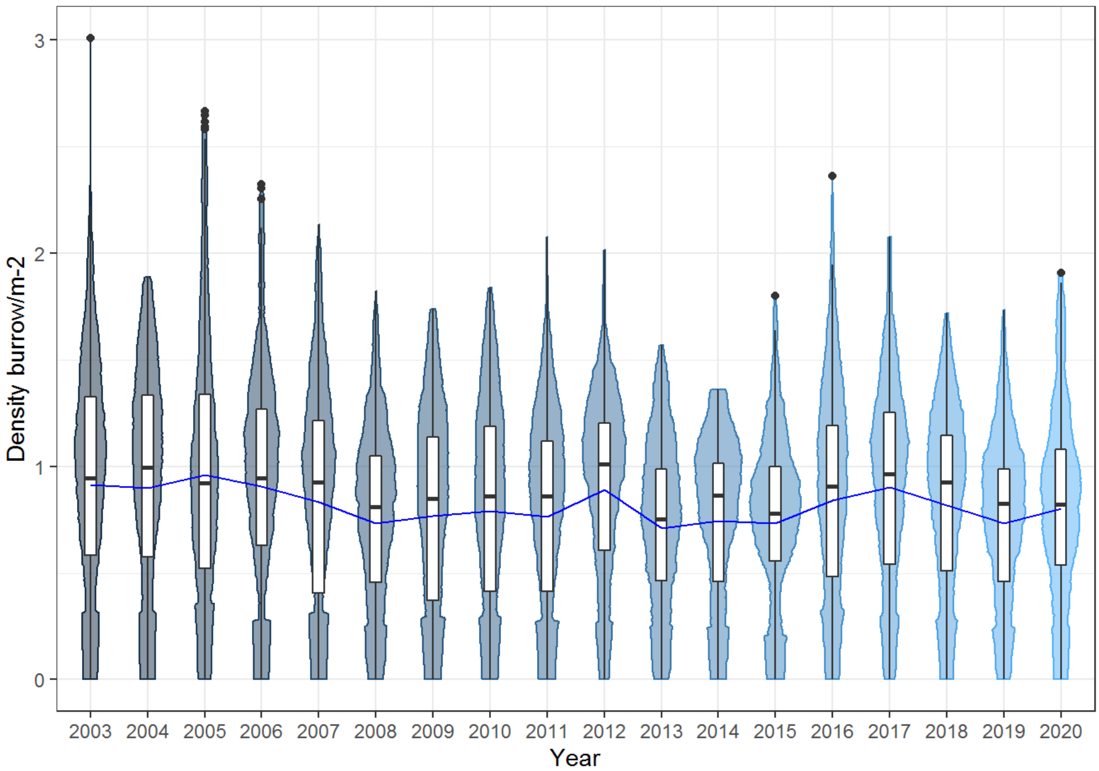

Figure. 2: Times series of adjusted burrow density (Violin and box plot).

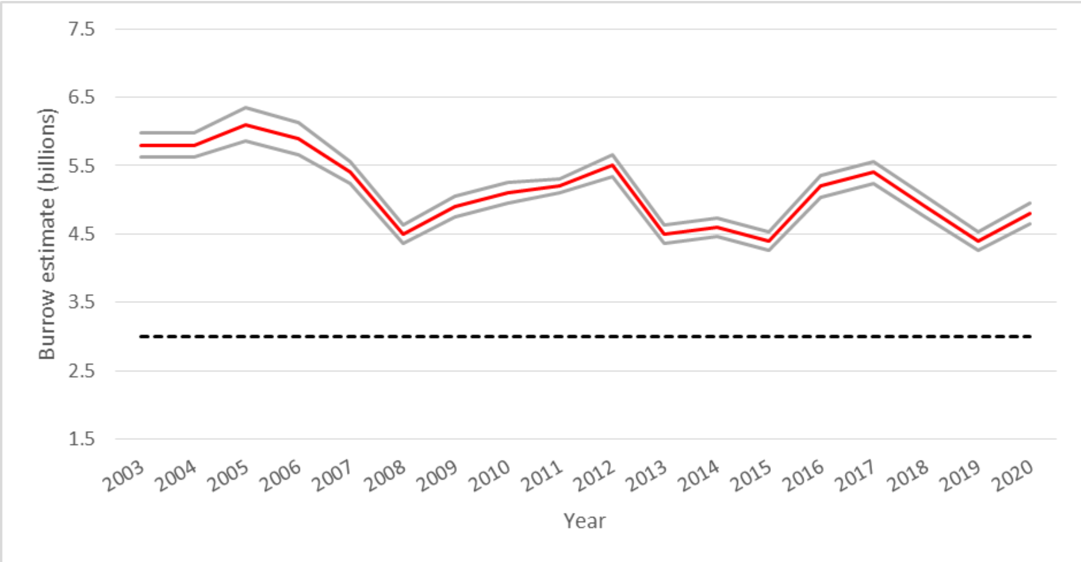

Figure. 3: Time series of mean density and total abundance (with confidence intervals) with reference levels.

UK Scotland

(Adrian Weetman, Gerald McAllister)

Marine Scotland Science (MSS) based in Aberdeen, Scotland, UK, carried out two underwater TV camera based surveys (UWTV) in Scottish waters in 2020. Both surveys required modifying in some way; the January trip aboard MRV Alba-na-Mara (Marine Research Vessel) due to the weather and June's trip onboard the MRV Scotia due to the impact of COVID related restrictions. These same restrictions also resulted the cancelation of the east coast survey in August aboard MRV Alba-na-Mara, for which the MRV Scotia survey was adapted to encompass the survey requirements that were scheduled for MRV Alba-na-Mara, ensuring all six of the main Function Units (FU's) in Scottish waters were surveyed during the calendar year. As illustrated in Figure 1 below, the 2020 survey data continued to add to the relatively long history of UWTV surveys carried out by MSS which began in 1992.

The equipment used in 2020 remained unchanged from recent previous years which included a Kongsberg 14-366 analogue video camera; four SeaLED lights; an odometer to calculate the distance travelled during each deployment and an altimeter to record the position of the camera in relation to the seabed (which is used to calculate the field of view). Each of the above mentioned devices were used on the TV sledge, with the drop frame only requiring the Kongsberg camera and four SeaLED's. A mini van Veen sediment sampler was also utilised, but only on the January MRV Alba-na-Mara survey. Only the sledge was used to carry out *Nephrops* abundance work, and both surveys fully met their planned objectives.

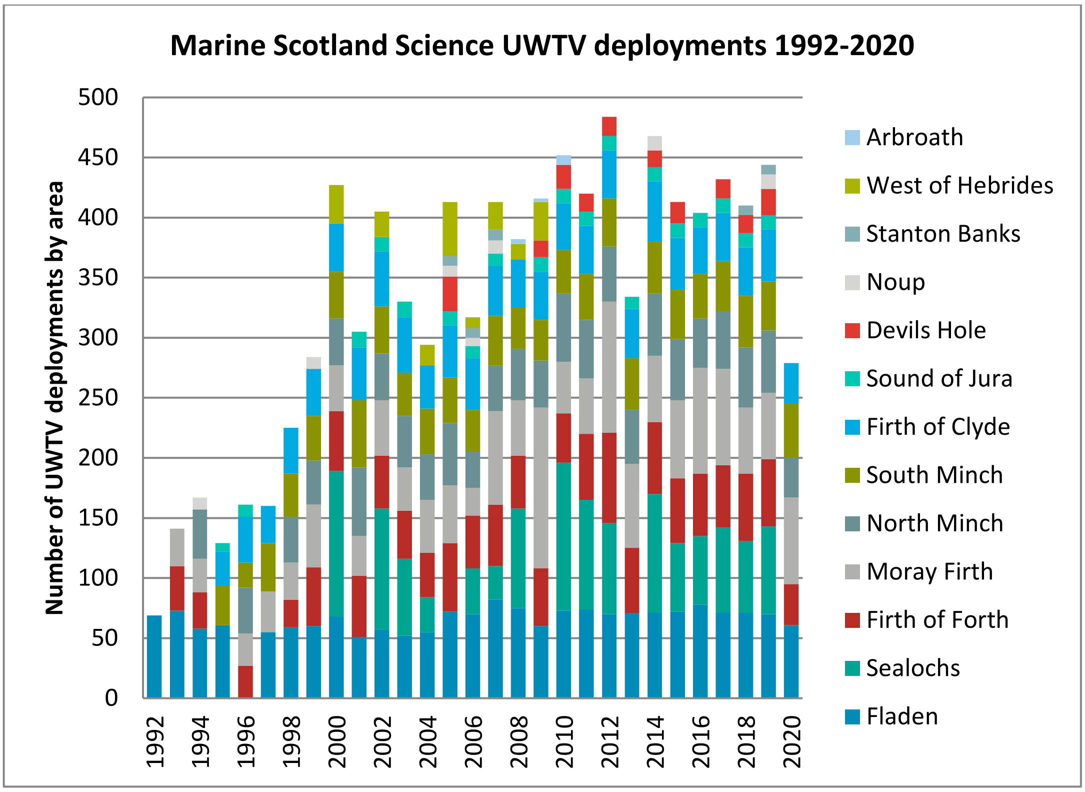

Figure 1. Time series of UWTV sledge and drop frame deployments by MSS for all areas surveyed, in relation to *Nephrops* burrow abundance, habitat mapping and comparative trials.

MRV Alba-na-Mara, 6 - 22 January 2020

The annual underwater television (UWTV) west coast research and support survey was carried out aboard MRV Alba-na-Mara during 6 – 22 January 2020. This non-Data Collection Framework funded survey successfully completed a number of objectives to further aid the annual assessment surveys carried out in the summer months and to address issues raised both at the *Nephrops* UWTV survey Working Group (WGNEPS) and from different programmes within MSS.

Although scheduled to carry out survey work on the west coast of Scotland, where scientific equipment and areas used in experiments could be guaranteed to be undisturbed by commercial trawler activity, the weather proved too poor in the short and medium term to allow the vessel safe passage west. Therefore the survey was relocated to west Moray Firth where shelter from the weather could be provided and commercial activity was minimal, with the work programme amended accordingly (Figure 2).

The first of many activities completed during this survey was to deploy a self-supported lander equipped with a time lapse camera, light source and power supply. This lander was designed to be left at specific sites to monitor bioturbation and benthic rejuvenation post-commercial activity (e.g. gravel extraction, oil-well capping, marine protected areas, etc.) for up to a year. However diversifying the utilisation of the lander has been encouraged and used on previous UWTV surveys. Ideally, the lander should be deployed in areas with high Nephrops burrow densities to observe Nephrops activity around burrow complexes, but due to potential commercial trawler activity in the new work area and therefore the high risk this placed on the lander, the lander was located just off the muddy habitat on the south side of the firth. The footage recovered from the nine days in situ (188 images) showed hard ground with considerable sea urchin activity (Echinus esculentus), interactions between various velvet crabs (Necora puber) and other passing fauna. These images were of interest to other programmes within MSS and added to the MSS image bank.

The survey then went on to undertake sledge and drop frame comparison trials. This work first began in 2012 as an opportunistic activity but in more recent years, with the realisation of the importance of this work, this activity has been scheduled into the survey programme. The purpose of the exercise was to survey the same ground with the well-established, peer reviewed approach using the TV sledge, and then re-examine the same grounds using the drop frame, which operates the with camera at a different angle and height to that of the sledge arrangement, and therefore a different field of view. By replicating the tows, over time it is hoped a correlation can be found between the two approaches, allowing the drop frame to be used to survey areas currently beyond the scope of the sledge (areas with creels, smaller grounds, areas where there is a potential risk of impact with hard ground, etc). Six sites were identified as appropriate to this work, providing a variety of *Nephrops* burrow densities and water clarity. At each site the sledge was deployed five times, with each deployment being parallel and 50m apart, and towed over a distance of approximately 200m. Following this, three drop frame deployments were carried out at 90^0 to the path the sledge took, and within the survey extent of that which was surveyed by the sledge, ensuring the same grounds were surveyed (Figure 3). The footage was reviewed in accordance with WGNEPS guidance, using Lin's concordance correlation coefficient

(Lin's CCC) to highlight where additional reviewer input was required. Further datasets are required before analysis can be carried out.

Following the comparison trials, two sites were identified suitable to undertake burrow recovery trials. The aim of this work was to add to previous data in order to determine the time required for *Nephrops* to re-establish potentially damaged burrow entrances following commercial fishing activity. At each site the sledge was deployed five times along a linear track. This data provided baseline *Nephrops* abundance data, prior to trawling over both sites with a commercial Jackson *Nephrops* trawl. Over the following days the UWTV sledge was deployed along the original sledge tracks, frequently observing the tracks created from the previous deployments, confirming the same grounds were being re-examined. To ensure the trawling had as little impact on the local *Nephrops* population as possible, both in removals and relocation of individuals, the cod-end of the trawl was left open. All the footage was reviewed at sea in accordance with WGNEPS guidelines, and the statistical analysis of these data are due to be undertaken in the near future.

In addition to the main objectives as described above, other trials were carried out in conjunction to this work. Such activities included mounting two parallel red, point lasers 7cm apart on the sledge and in line with the video camera. This provided a scale to gauge the size of confirmed *Nephrops* burrow entrances that video reviewers were confident in identifying. This work established that it was possible to identify entrances with a diameter as small as 2.5 cm – although smaller burrows were also positively identified, however they did not pass between the laser points and therefore it was not possible to provide evidence to establish the size of these entrances. This provided confidence in the abilities of the reviewers in their reviewing technique.

Continuing to investigate the possibilities of MSS upgrading the video format to high definition (HD), but being limited by the lack of fibre optic capabilities, a self-supported HD camera was mounted to the sledge to record in parallel with the existing analogue camera, providing the same comparative footage. This model of camera stored the video recording locally but significantly, allowed the footage to be accessed and downloaded via wifi, circumventing all the associated issues of removing HD cameras or SD cards from the sledge to access the footage (i.e. changes in camera position, changes to the field of view, the time aspect in moving equipment and downloading, etc). Video footage from several tows was obtained and assessed on returning to the Laboratory. Despite utilising a highgrade HD flat screen monitor and having obtained a higher quality image than previously experienced using HD cameras without using fibre optic cable, the footage from the existing analogue camera and CRT monitors remained superior; and when also considering the limiting, bespoke software involved and the significant costs involved, the decision was taken not to progress further with this approach.

The survey also introduced four new members of staff the UWTV surveys: two engineers and two scientists. The survey provided a training opportunity for all involved, including biological sampling following a fishing trawl. In addition, the engineers recently underwent closed water training of a remotely operated vehicle (ROV) and this survey provided the time and location to operate the ROV at sea for the first time.

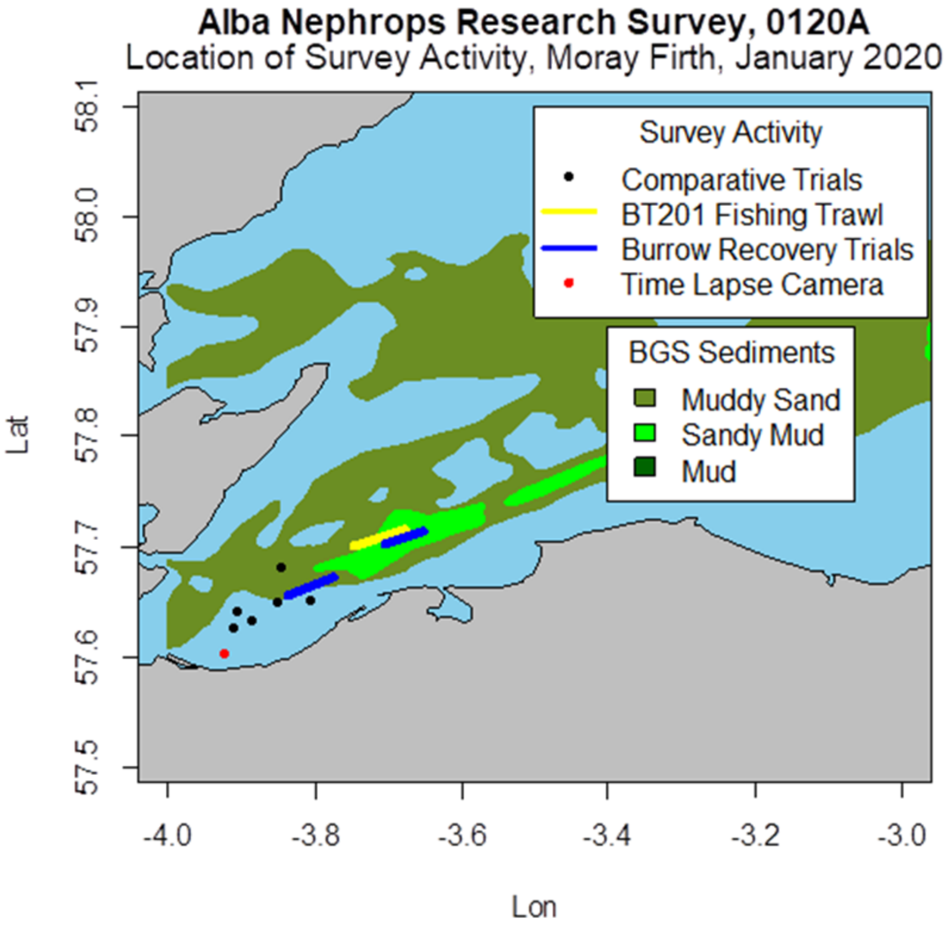

Figure 2. The location of survey activity in the western Moray Firth aboard MRV Alba-na-Mara during January 2020.

MRV Scotia, 14 - 30 June 2020

The annual Fladen and west coast UWTV survey aboard MRV Scotia was the first MSS survey to be carried out since the first national UK lockdown in response to COVID which began on 23 March 2020. The survey programme had to be significantly altered due to the pandemic and the late decision for the survey to go ahead. The most significant alterations included:

- only 17 days were available rather than the standard 23;
- the 2m social distancing guidance reduced the numbers of MSS staff permitted to the survey from the standard eight or nine down to five, with only three of these staff trained in *Nephrops* burrow identification, rather than the usual five or six staff;
- with fewer staff the working pattern was modified to two 12 hour shifts, each shift with two staff – leaving little time for reviewing footage and paperwork – much of which was redirected to the fifth member of the team;
- due to the 2m guidance it was not going to be possible for MRV Alba-na-Mara to carry out the annual Moray Firth and Firth of Forth survey in late summer, and so these two areas had to be incorporated into the MRV Scotia survey – with no additional time being provided;

- including these two new areas in the MRV Scotia survey significantly increased the mileage and associated steaming time, reducing UWTV deployment time.

Considering these added challenges it was not possible to conduct all the standard activities during the survey, and priorities were identified and modifications applied:

- UWTV activity in the six main functional units was the main priority of the survey;
- no sediment samples were taken;
- no trawling was undertaken;
- the Noup, Devils Hole and the Sound of Jura were not surveyed;
- the planned number of stations in each area were reduced proportionally in relation to previous years, depending on various factors (except in the South Minch where variability in the area traditionally remained high).

Following modified COVID inductions, training and a review of amended risk assessments aboard the vessel, the first area to be surveyed was the Firth of Forth, where station numbers were reduced significantly as the area has a well-established, steady fishery and homogenous grounds. Fladen was then surveyed, and although the abundance data has been relatively stable over time, there has been a slight downturn over the last three years. In addition, due to the size of the grounds any major reduction in station numbers would have a disproportionally affect on the analysis, and so the number of stations were reduced the least at Fladen. The survey then continued down west side of the North Minch and into the South Minch. With the North Minch survey area based on one strata (that of VMS data) this allowed a slightly larger reduction in stations than other areas; whereas the South Minch traditionally showed high variance due to a wide range of benthic strata over a large geographical area and therefore planned station numbers remained unchanged. In both Minches, a number of COMPASS moorings were recovered and replacement arrays deployed. These moorings are part of a long term, Interreg project involving five institutions which aims to build cross-border capacity for effective monitoring and management of Marine Protected Areas (MPAs). The moorings associated with this survey were laid on the seabed with various acoustic devices attached to enable the monitoring of passing fauna by recording and counting the number of vocal interactions to establish the frequency and variety of cetaceans visiting the west coast of Scotland.

The vessel then proceeded into the Clyde, and although a relatively small area to survey, the benthic variability resulted in only a marginal reduction in the number of stations in this functional unit. Due to the reduced number of days available on this survey, the ability to adapt the survey plan to ensure surveying the Clyde was conducted during the weekend (when trawler activity is not permitted) was not possible. Therefore the survey was conducted during the week resulting in poorer visibility which was reflected in the QC plots. On completing all the scheduled TV stations the vessel recovered a marine passive acoustic monitoring mooring (MarPAMM) from alongside the MPA to the south of the Isle of Arran, which was also providing data for the COMPASS project (Figure 3).

The remaining stations in the South and then North Minch were completed on the return leg of the journey. However due poor weather the expected time available to survey the Moray Firth was reduced, impacting on the achievable number of stations even further. As a result less than half the number of the stations that are normally surveyed during the August/September MRV Alba-na-Mara survey were conducted. In addition, although randomly generated, many of these stations appeared to be located near to the edge of the known muddy habitat. This increased the variability between counters and introducing a third counter on this occasion did not resolve the situation.

Due to the limited number of reviewers aboard and the reduced time available for reviewing whilst at sea, some first stage counts and a number of third counts had to be completed following the survey. This had a significant impact on the provision of data ahead of the annual assessment working groups, and although all required deadlines were met, this situation highlighted the need to ensure time was made available for critical staff post-survey if this atypical scenario was ever repeated.

All video footage, both at sea and onshore, was reviewed in accordance with WGNEPS guidance, with quality control being carried out on all data using Lin's CCC, with third counts applied where thresholds were not met (see Table 1 below). Reference sets for the three remaining areas ((Firth of Forth (FU 8), Moray Firth (FU9) and Clyde (FU 13) using 2018 footage was collated, completing the revised reference sets for MSS. However due to staff and time constrictions during the survey the footage remained unassessed.

All survey data were uploaded to the bespoke MSS UWTV database.

Conclusions/recommendations/aspirations:

- To further encourage and promote national and international staff exchange.
- 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 increase the number of MSS staff suitably trained to assist in UWTV surveys.
- To submit tenders to replace the failing motion compensated sea going balances.
- To submit tenders for the provision of a copper/fibre optic hybrid cable and associated high definition camera.
- To prepare and present at WGNEPS 2021 updated analysis of *Nephrops* morphometric and maturity related data, gathered from UWTV surveys.
- To prepare and present at WGNEPS 2021, updated analysis of *Nephrops* weight/length data, gathered from UWTV surveys.
- To ensure sufficient staff aboard surveys to carry out all analysis in a timely fashion; or if footage has to be reviewed post-survey, to prioritise this work, ensuring sufficient time is allocated to achieve this task as soon as possible.
- To continue collaborating with the Joint Nature Conservancy Council (JNCC) in analysing UWTV footage for associated studies; and continue to contribute to the UK marine image collation, processing, storage, annotation and promotion work shops (The Big Picture) chaired by JNCC.

Table 1 Summary of *Nephrops* burrow abundance related activities carried out within the six survey areas during the MRV Scotia cruise in June 2020. 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 and/or a legacy component.

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
Firth of Forth	34	0	0	0.5	61.7	RS –S
Fladen	61	0	0	0.7	49.0	RS –S
North Minch	33	0	0	0.5	75.8	RS – E & F
South Minch	45	0	0	0.5	55.5	RS -S
Clyde	34	0	0	0.5	47.0	RS -S
Moray Firth	34	0	0	0.5	54.1	RS –S
Totals	231	0	0			

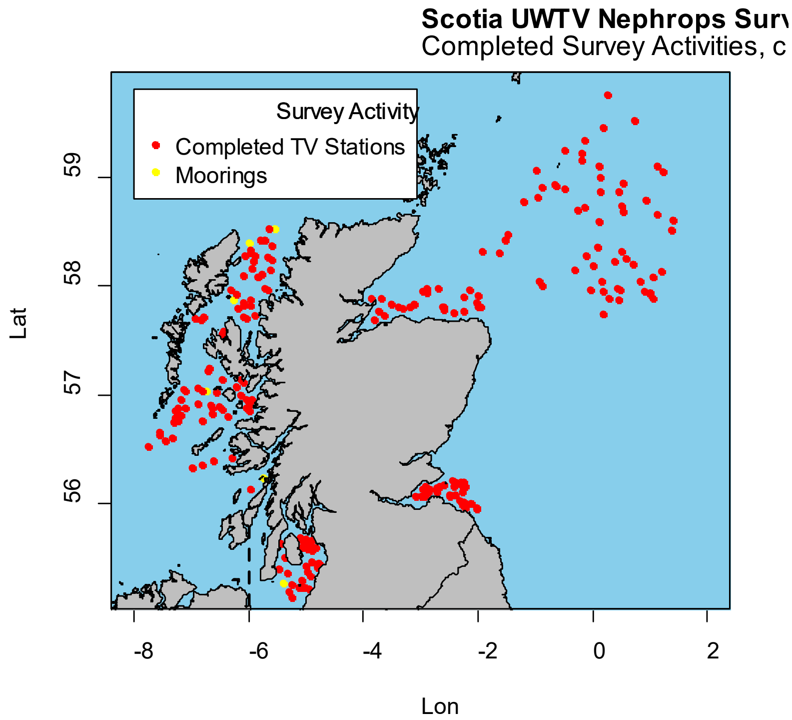

Figure 3. Map illustrating the location of the UWTV stations and COMPASS mooring recoveries/deployments that were conducted within the six survey areas during the MRV Scotia cruise during June 2020.

UK England FU 6

(Charlotte Reeve)

Functional Unit	FU 6	Area name	Farn Deeps
Survey design	Fixed Grid	Previous surveys	1997-2019 (Except 1999 & 2000)
Country (ies)	England	Vessel name (s)	RV Cefas Endeavour
Survey code (s)	CEND0920	Dates (start/end)	29th June - 10th July 2020
Number scientific staff	10	Staff exchanges	0
Number of stations (planned/completed/used in analysis)		110/110/110	
Deviations from the survey plan (e.g. coverage/weather related problems, technical problems, potential biases, etc.)		Inclement weather from 4th to 5th July slowed operations and reduced visibility at 10 stations.	
Distance over ground source used	Ships positioning/transponder	Average field of view (cm)	Width of view 82.5 (distance between lasers)
Adjusted mean density	0.35	Adjusted abundance, CV	1102 million
Overall footage quality (poor, medium, good)		76% Good, 21% Moderate, 3% Poor	
Reference footage for survey area generated		No. Footage from 2018 used.	
Quality control of station counts (Lin's CCC or consensus count) State Lin's CCC threshold		Lin's CCC, threshold 0.5	
Other survey activities (CTD, Trawl, sediment samples, sediment profile images, % stations with trawl marks recorded, presence/absence sea-pen distribution etc.)		CTD twice daily. ESM2 logger attached recording turbidity reading, depth, salinity, and oxygen levels.	
Data storage, level of analysis and dissemination (by data type)		Nephrops burrow counts	**Storage**: MP4 files **Level of Analysis**: Krigged **Dissemination**: ICES Advice, WGNSSK
		CTD	Twice daily
		Trawl	None
		Sediment	None
		Other	None

Table 1: UWTV Summary FU 6.

Year	Number of Stations (used in the analysis)	Abundance adjusted estimate (millions of burrows)	CV on Burrow estimate %
1997	87	1500	4.3
1998	91	1090	4.2
1999	-	-	-
2000	-	-	-
2001	180	1685	2.0
2002	37	1048	5.5
2003	73	1085	4.2
2004	76	1377	3.7
2005	105	1657	4.6
2006	105	1244	4.7
2007	105	858	1.4
2008	95	987	2.0
2009	76	682	2.8
2010	95	785	1.4
2011	97	878	1.0
2012	97	758	0.9
2013	110	706	1.3
2014	110	755	0.9
2015	110	568	1.3
2016	110	697	1.2
2017	110	909	1.4
2018	109	950	1.2
2019	91	1163	1.2
2020	110	1102	1.1

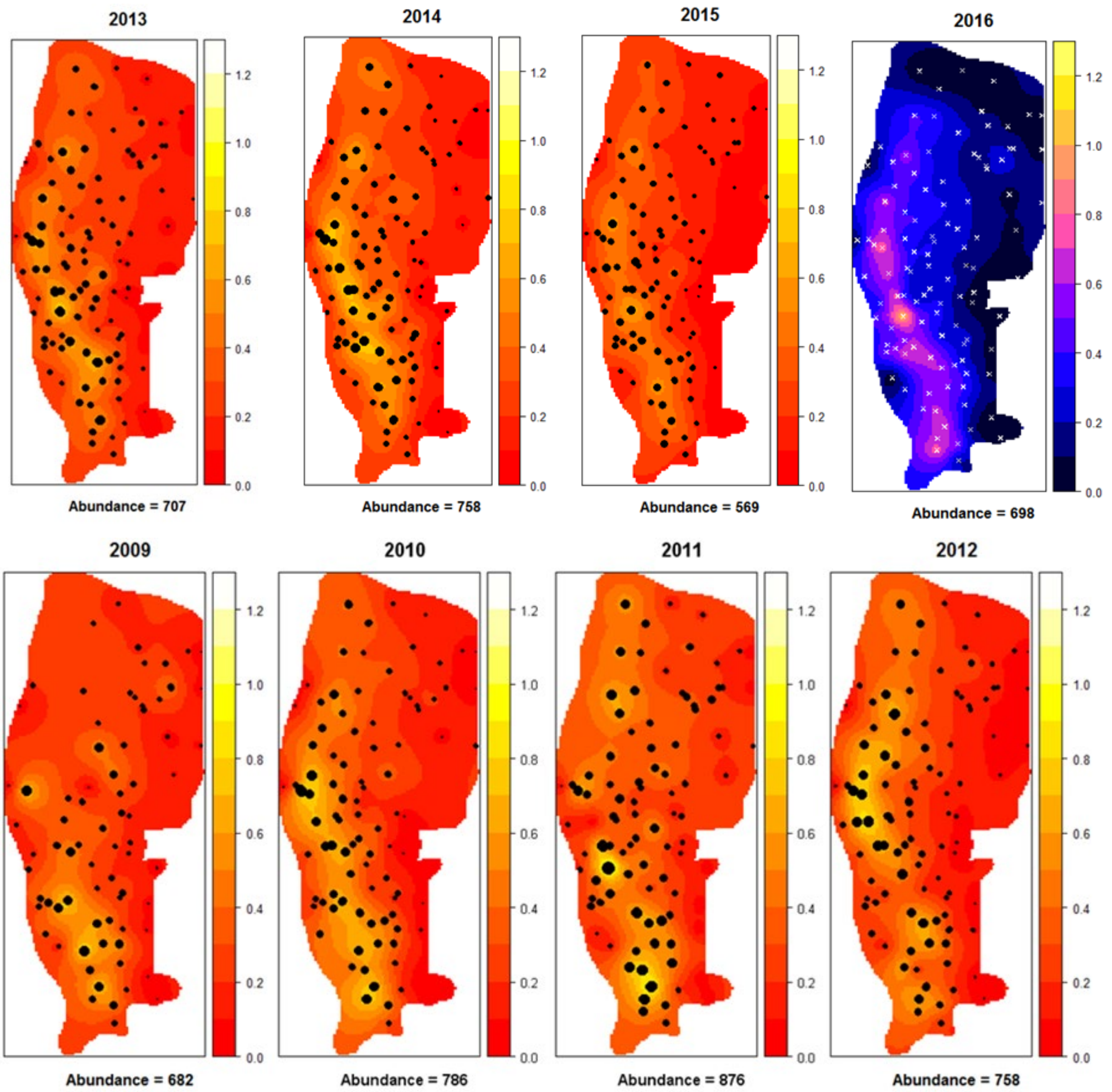

Figure 1a: FU 6 Map of density by station for each year.

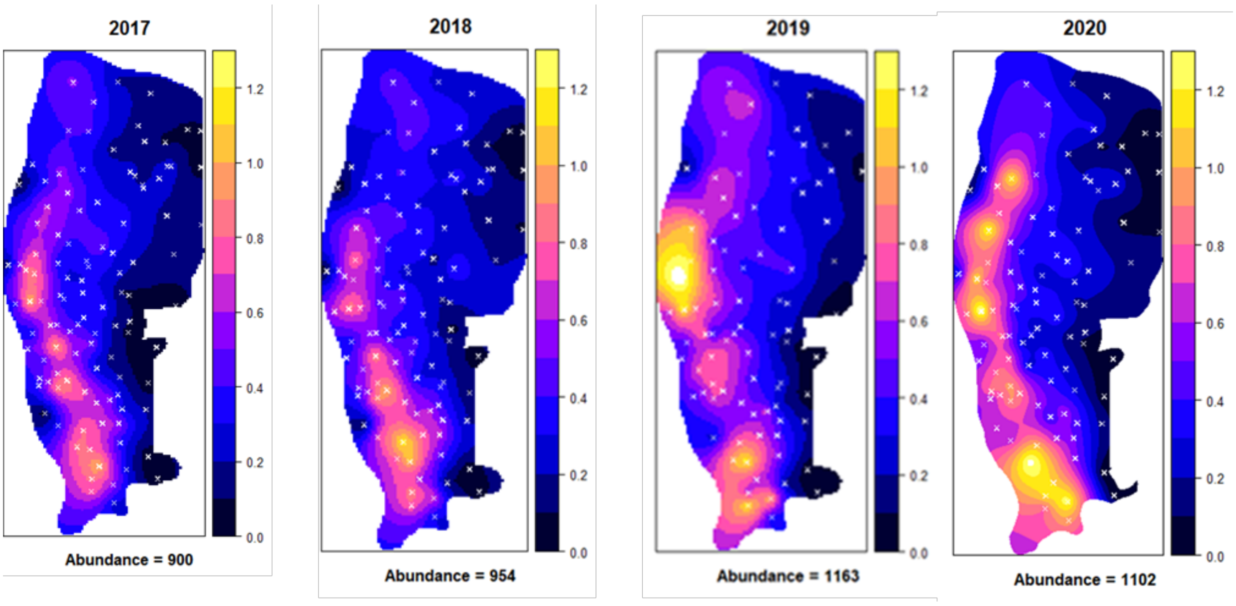

Figure 1b: FU 6 Map of density by station for each year.

UK England FU 14

(Charlotte Reeve)

Functional Unit	FU 14	Area name	Eastern Irish Sea
Survey design	Fixed Grid	Previous surveys	2007-2019
Country (ies)	England & N.Ireland	Vessel name (s)	RV Corystes
Survey code (s)	CO3120	Dates (start/end)	6^{th} – 8^{th} July 2020
Number scientific staff	See FU 15 report	Staff exchanges	0
Number of stations (planned/completed/used in analysis)		46/43/43	
Deviations from the survey plan (e.g. coverage/weather related problems, technical problems, potential biases, etc.)		See FU15 report. No Cefas staff exchanged on survey due to Covid-19, Cefas participated in station counting.	
Distance over ground source used	Ship positioning	Average field of view (cm)	68cm
Adjusted mean density	0.46	Adjusted abundance, CV	496 million (CV: 8.6%)
Overall footage quality (poor, medium, good)		No footage quality recorded	
Reference footage for survey area generated		No	
Quality control of station counts (Lin's CCC or consensus count) State Lin's CCC threshold		Lin's CCC threshold 0.5	
Other survey activities (CTD, Trawl, sediment samples, sediment profile images, % stations with trawl marks recorded, presence/absence sea-pen distribution etc.)		CTD Presence/absence ancillary data collected	
Data storage, level of analysis and dissemination (by data type)		Nephrops burrow counts	**Storage**: DVD **Level of Analysis**: Krigged **Dissemination**: ICES Advice, WGCSE
		CTD	Every station
		Trawl	None
		Sediment	None
		Other	None

Table 1: FU 14 UWTV Summary.

Year	Number of Stations (used in the analysis)	Abundance adjusted estimate (millions of burrows)	CV on Burrow estimate %
2007	-	-	-
2008	32	407	-
2009	32	350	-
2010	26	422	-
2011	26	449	11.8
2012	26	693	7.8
2013	31	487	9.1
2014	34	449	10.7
2015	42	590	7.9
2016	48	429	12.6
2017	45	579	7.8
2018	46	513	12.6
2019	46	399	9.3
2020	43	496	8.6

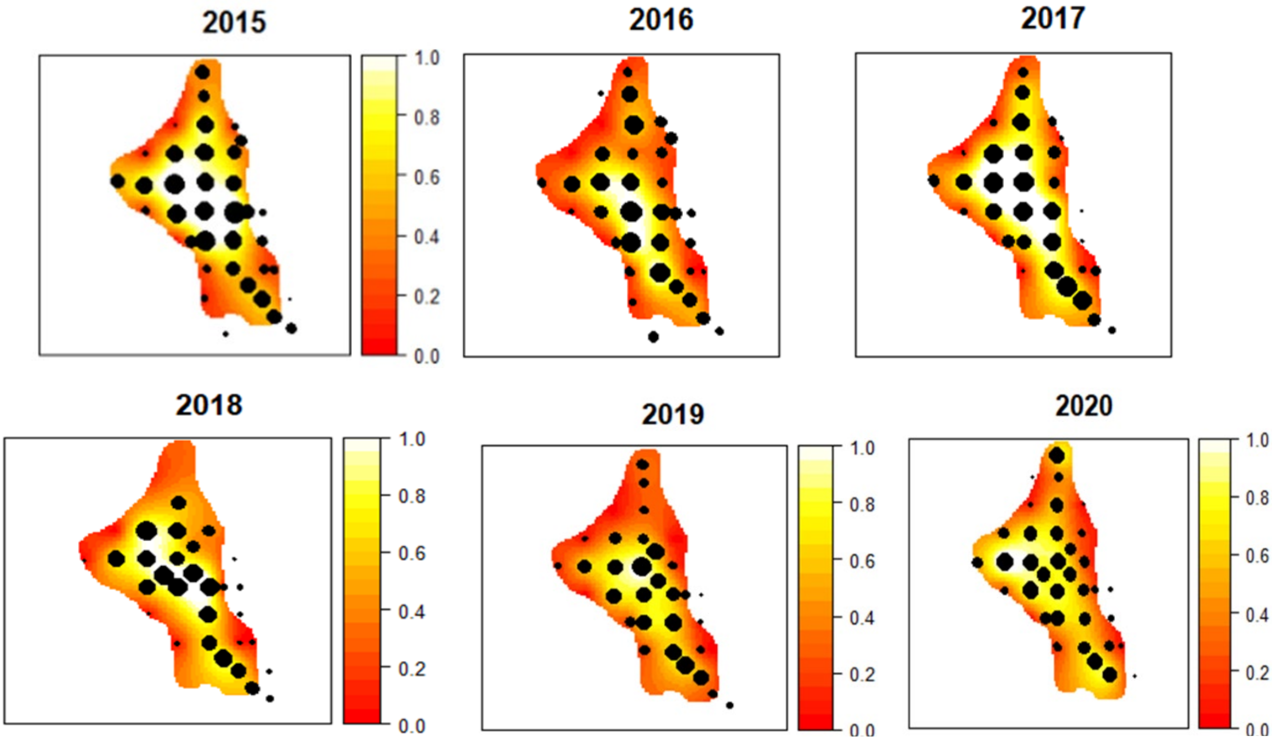

Figure 1: FU 14 Map of density by station for each year.

Denmark and Sweden FU 3-4: Skagerrak and Kattegat

(Kai Wieland, Patrik Jonsson)

Functional Unit	FU 3&4	Area name	Skagerrak/Kattegat
Survey design	Stratified random, with buffer since 2017	Previous surveys	2008-2010: DK only, exploratory 2011-2013: 6 strata 2014-2016: 7 strata since 2017: 9 strata, SWE: additional stations in creel area (not included in the analysis)
Country (ies)	Denmark and Sweden	Vessel name (s)	DK: RV Havfisken SWE: RV Svea
Survey code (s)		Dates (start/end)	DK: 17/4 - 23/4/2020 SWE: 28/3 – 4/4/2020
Number scientific staff	DK: 2 SWE:	Staff exchanges	none
Number of stations (planned/completed/used in analysis)		DK: 103 / 102 / 98 SWE: 103/103/96	
Deviations from the survey plan (e.g. coverage/weather related problems, technical problems, potential biases, etc.)		DK: uneven bottom and/or poor visibility at 5 stations SWE:	
Distance over ground source used	Vessel GPS	Average field of view (cm)	RV Havfisken: 66 cm RV Svea:
Adjusted mean density		Adjusted abundance, CV	
Overall footage quality (poor, medium, good)		Good	
Reference footage for survey area generated		DK: yes (6 footages from 2018 survey), but yet no checked by external expert or a Swedish reader SWE: still to come for the new system	
Quality control of station counts (Lin's CCC or consensus count)			

<table>
<tr><td>Other survey activities (CTD, Trawl, sediment samples, sediment profile images, % stations with trawl marks recorded, etc.)</td><td colspan="2">DK: CTD</td></tr>
<tr><td rowspan="5">Data storage, level of analysis and dissemination (by data type)</td><td>Nephrops burrow counts</td><td>Excel files, .csv file with R-output for DK and SWE combined</td></tr>
<tr><td>CTD</td><td>DK: Institute's server, unprocessed raw data</td></tr>
<tr><td>Trawl</td><td></td></tr>
<tr><td>Sediment</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
</table>

2020 Swedish UWTV data not available at meeting due to COVID-19 disruption. This dataset will be analysed in 2021.

<u>Future work</u>

- Sweden to establish 6 reference footages from the 2020 survey
- Identify the most appropriate annotation tool for analyzing reference footages for both countries
- Swedish and Danish readers to count the 6 Danish references footage established from the 2018 survey and the 6 Swedish reference footages from the 2020 survey using an agreed annotation tool, and analyzing the results prior to work up the 2021 survey videos
- Report on Lin's CCC analyses together with the 2021 survey results to WGNEPS 2021 meeting

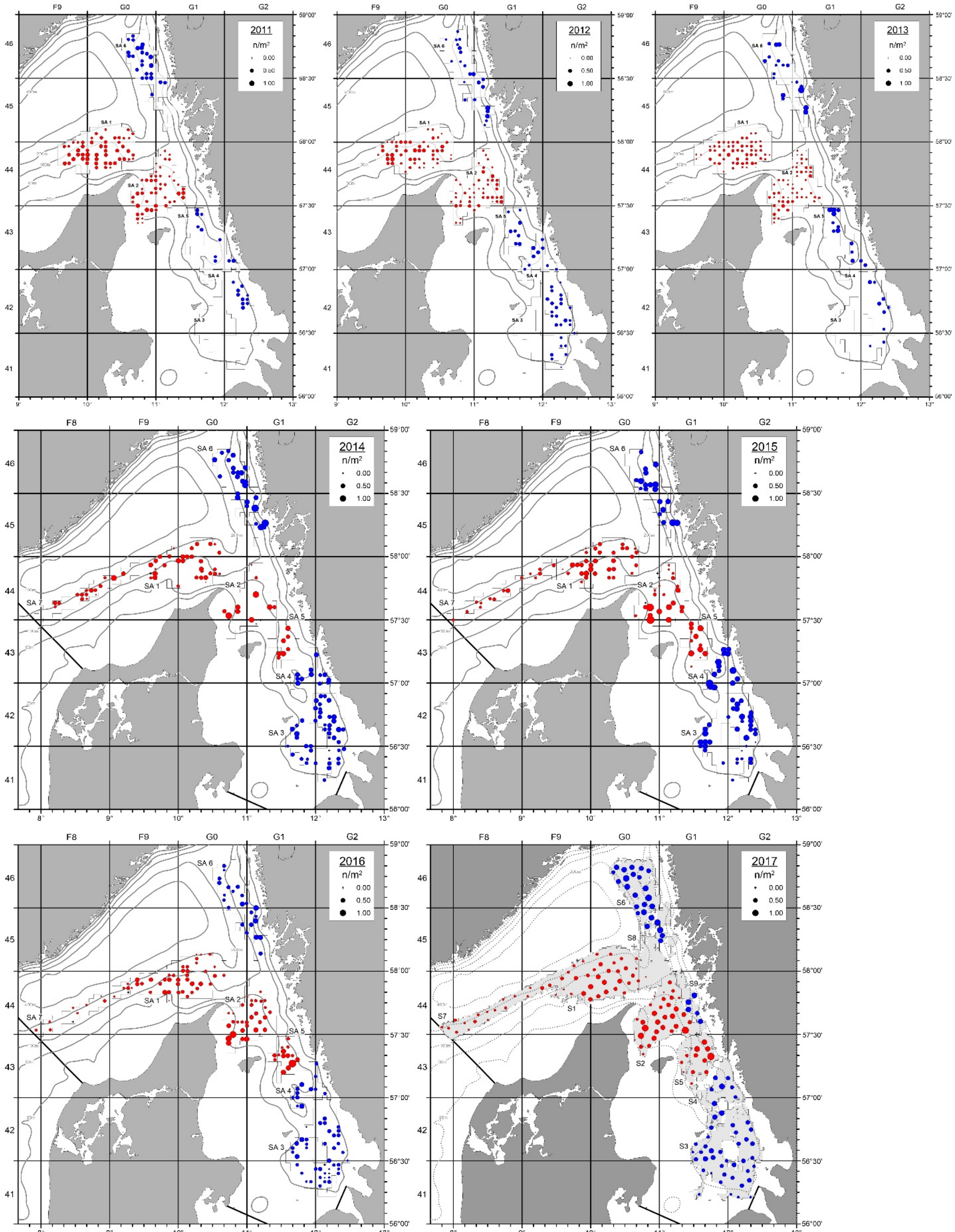

Figure. 1a: FU 3&4 (Skagerrak/Kattegat) *Nephrops* burrow density by station 2011 - 2017 (red: DK, blue: SWE).

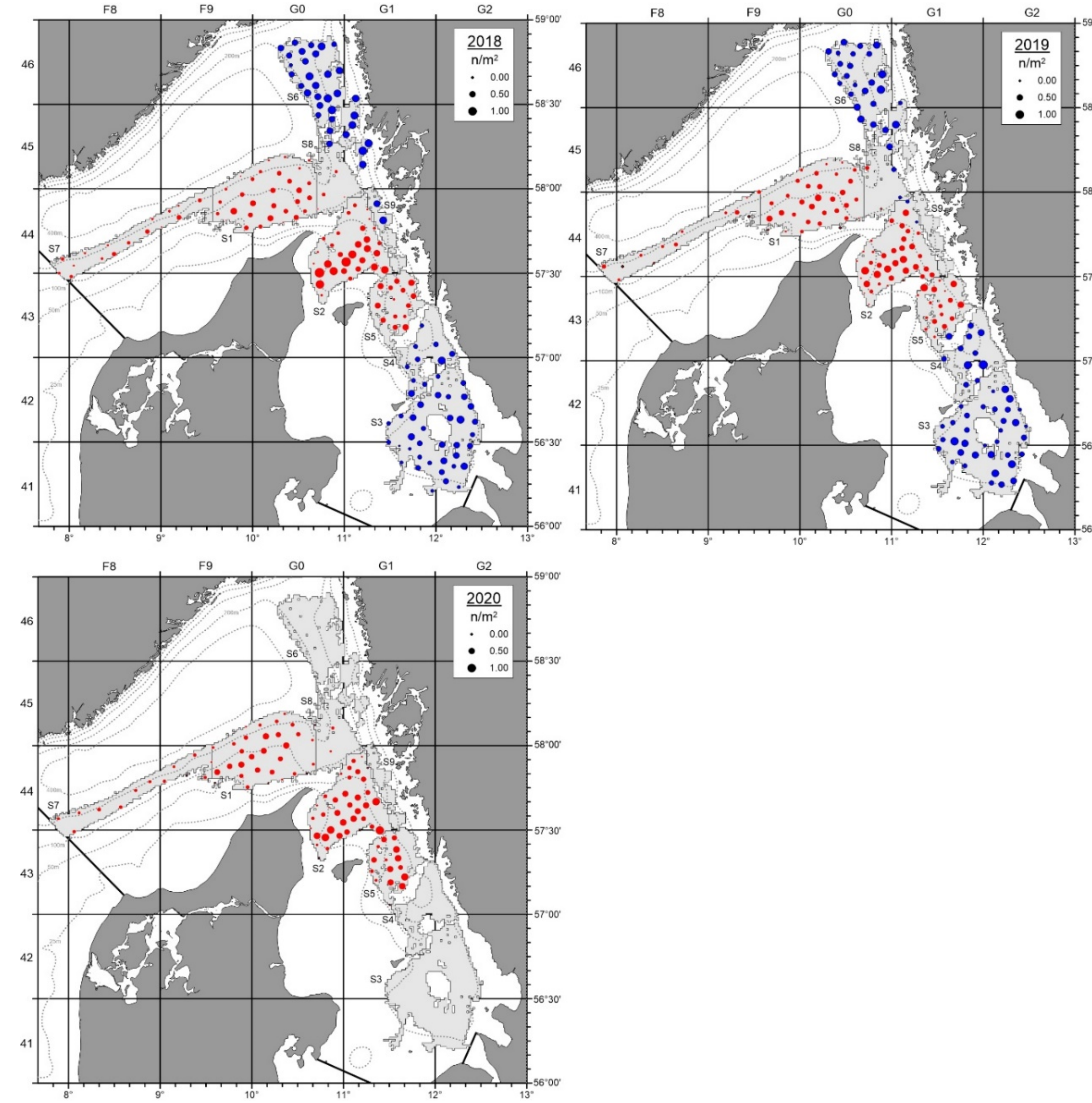

Figure. 1b: FU 3&4 (Skagerrak/Kattegat) *Nephrops* burrow density by station 2018 - 2020 (red: DK, blue: SWE).

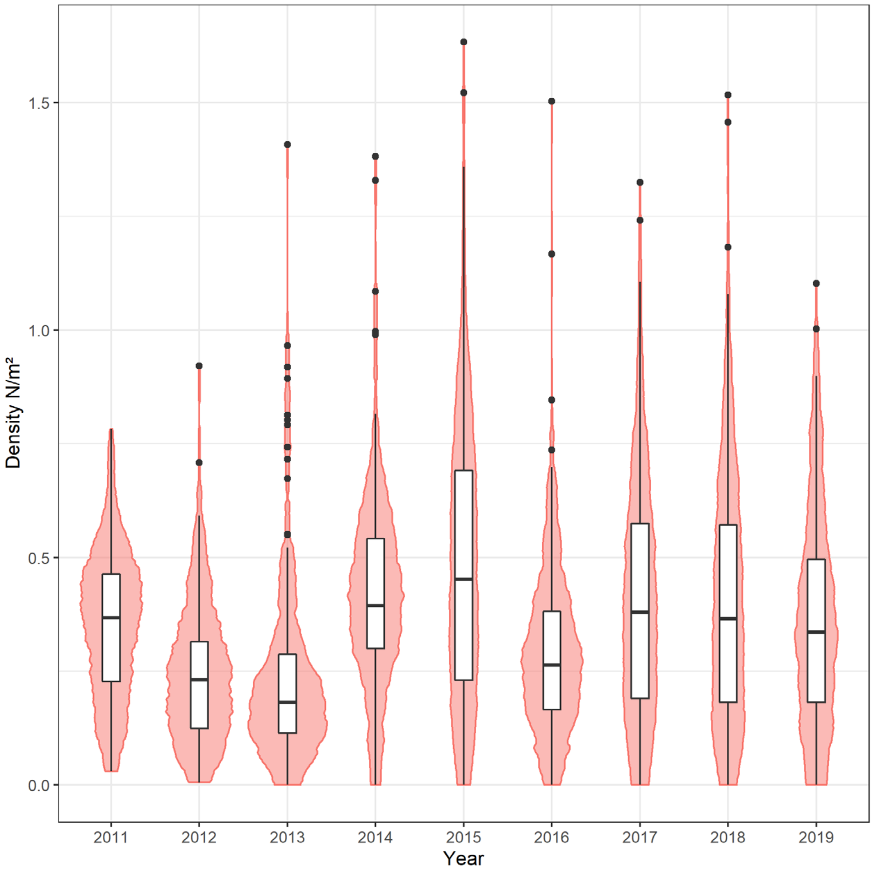

Figure. 2: FU 3&4 (Skagerrak/Kattegat) times series of *Nephrops* burrow density (The horizontal lines represents the medians, the boxes are the inter quartile range, the shaded areas show the kernel probability densities of the data at different values and the black dots are potential outliers).

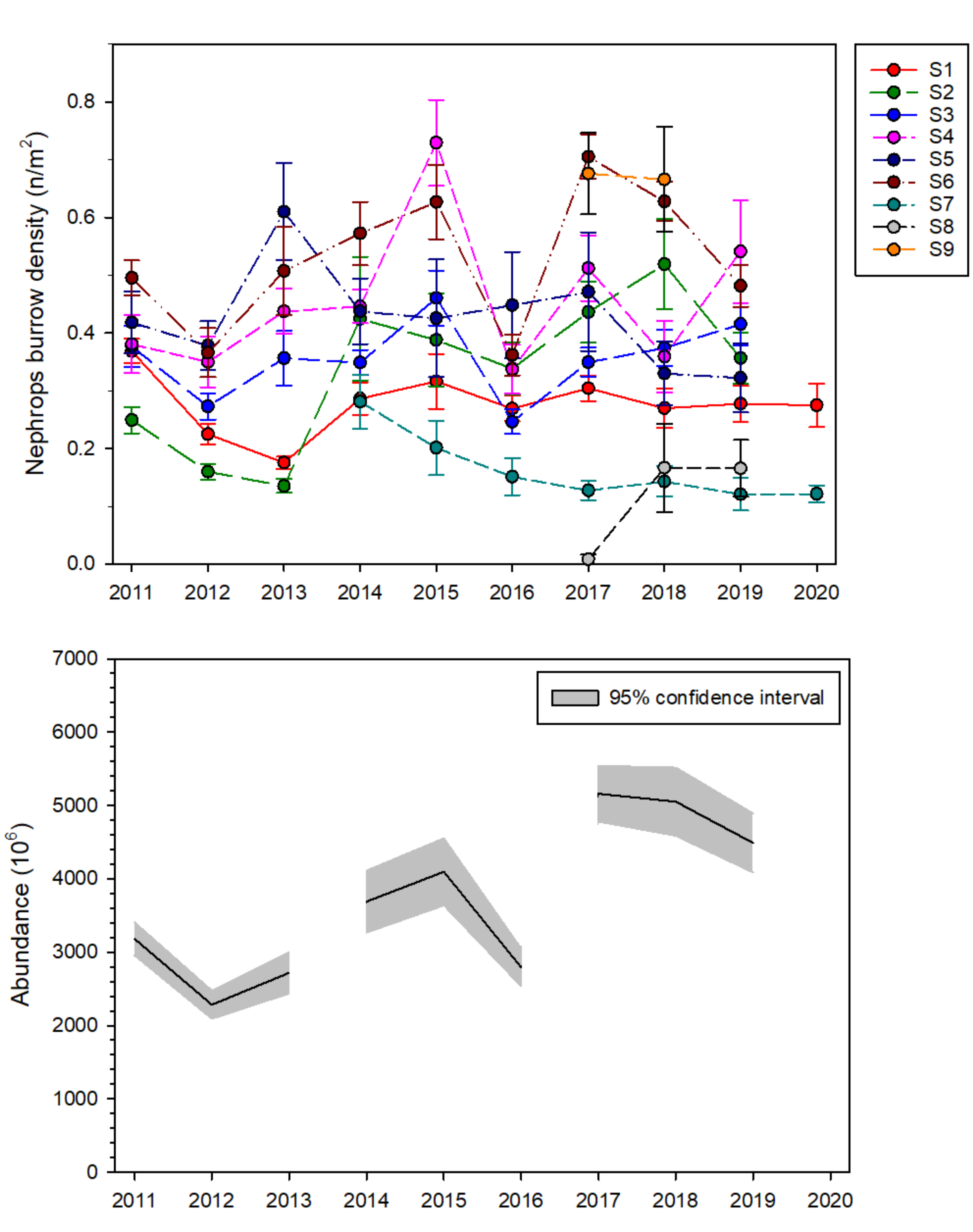

Figure. 3: FU 3&4 (Skagerrak/Kattegat) time series of *Nephrops* burrow mean density by stratum and total abundance with reference levels (error bars in upper panel represent standard error of the mean; shaded area in the lower panel represents the 95% confidence interval; note change in survey area and stratification between 2013 and 2014 and between 2016 and 2017; reference points for stock size are not defined for this stock).

Denmark FU 33: Off Horns Rev

(Kai Wieland)

Bi-annual survey.

No survey planned in 2020.

Next survey scheduled for 3 – 12 May 2021.

See ICES. 2020. Working Group on *Nephrops* Surveys (WGNEPS; outputs from 2019). ICES Scientific Reports. 2:16. 85pp. http://doi.org/10.17895/ices.pub.5968 for results of the previous surveys.

Spain FU 30: Gulf of Cadiz

(Yolanda Vila, Candelaria Burgos)

Due to COVID-19 pandemic the UWTV survey was not carried out in 2020.

See ICES. 2020. Working Group on *Nephrops* Surveys (WGNEPS; outputs from 2019). ICES Scientific Reports. 2:16. 85pp. http://doi.org/10.17895/ices.pub.5968 for results of the previous surveys.

Portugal FU 28-29: southwestern Portugal

(Cristina Silva)

Due to COVID-19 pandemic and vessel issues the trawl survey was not carried out in 2020.

France FU 23-24: Bay of Biscay

(Spyros Fifas, Jean-Philippe Vacherot)

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 surface involving in *Nephrops* is precisely delimited owing two information: (1) on the sedimentary structure of the seabed already taken into account during the former LANGOLF trawl survey on years 2006-2013 (5 spatial strata; Figure. 1); (2) on the systematic grid of video tracks combined with VMS data for the fishery (Figure. 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 1; Figure. 3).

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.

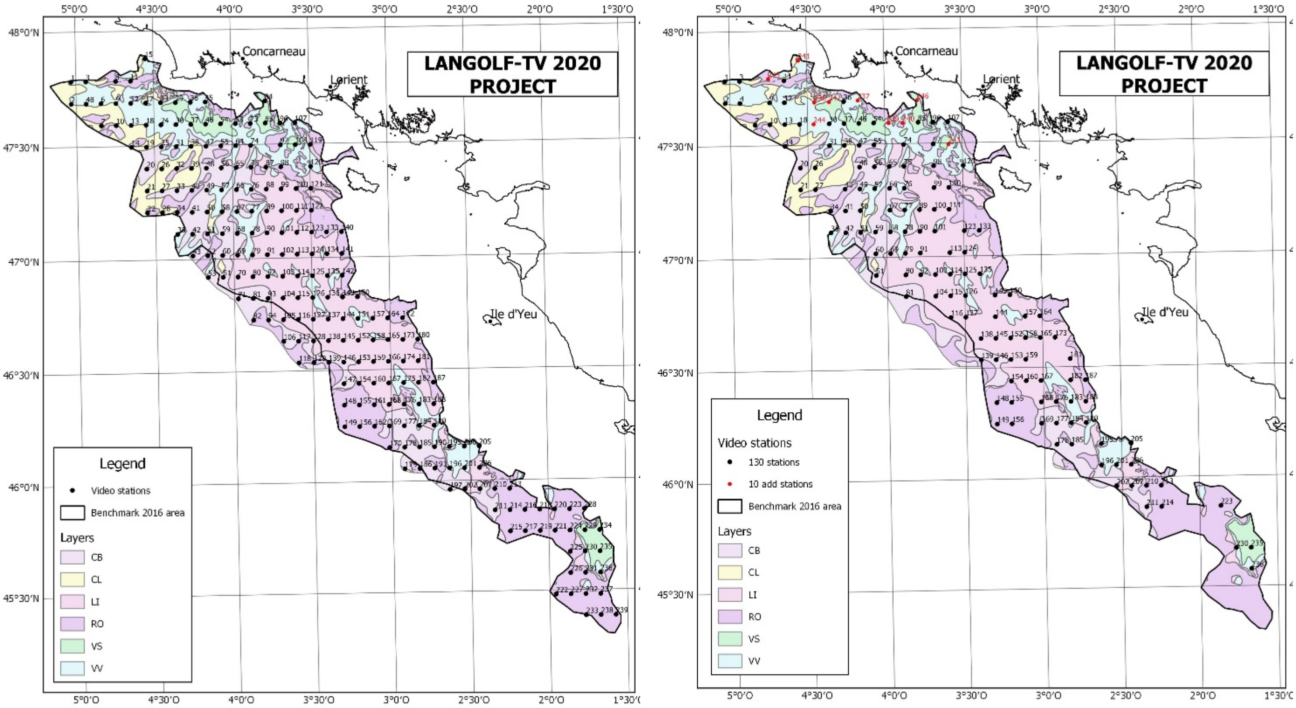

Figure 1. Spatial stratification of the Bay of Biscay according to sedimentary criteria as considered from the first UWTV survey onwards (2014) and sampling design 2020 before COVID-19 crisis (left) and finally retained (right).

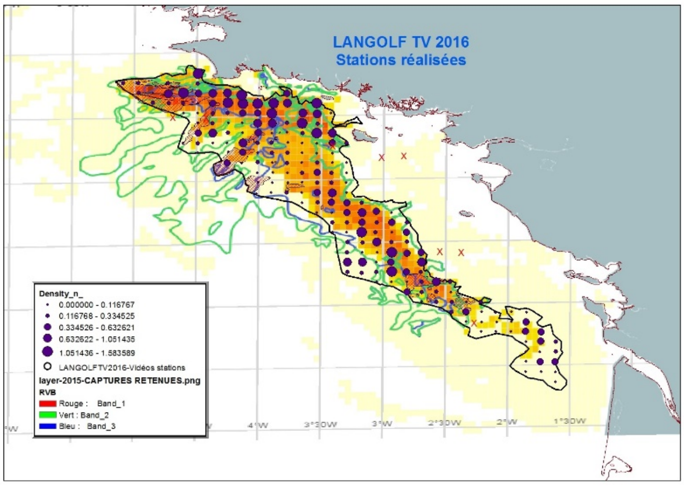

Figure 2. UWTV stations on a systematic grid and VMS data for retained catches of *Nephrops* (example of the year 2016; source: National Fisheries Direction; compilation: SIH Ifremer).

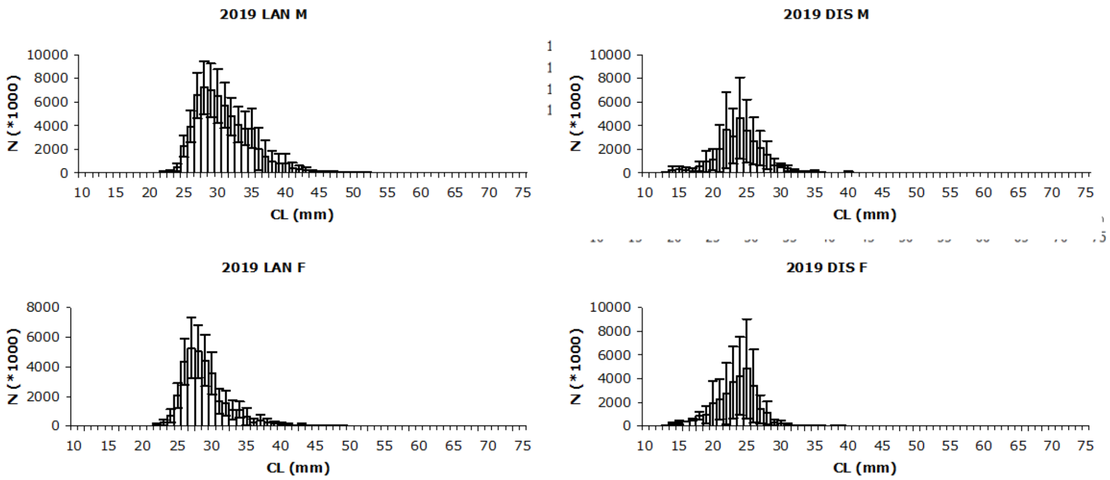

Figure 3. LFDs (size in carapace length, mm) for landings and discards by sex. Example of dataset 2019.

Sampling Protocol

In accordance with other routinely UWTV surveyed stocks, the sampling protocol applied since 2014 has been a systematic one advantaged by wider spatialised 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). 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. In 2019 a supplementary area of ≈930 km² was sampled with 7 validated stations whereas the standard benchmarked area contained 145 ones. In 2020, due to the COVID-19 pandemic, the survey initially scheduled at late April/early May was strongly compromised, before being re-scheduled from 22nd July to 4th August, with only two Irish scientists experienced in this type of mission in order to respect the obligatory social distancing on board (31 m vessel: "Celtic Voyager"; Irish company P&O). It was decided to reduce the sampling plan to 130 stations allowing to obtain statistically acceptable precision level of estimates and to make all video interpretations by Ifremer agents in lab after the end of the survey. The basis of the 2020's plan was the 2018's survey because its coverage was more complete than in 2019. Among the 2018's 184 validated stations contained in the Central Mud Bank benchmarked outline, 10 corresponding to zero burrows counted in 2018 as well as in 2019 were erased. The choice of 130 stations was ended by a random process eliminating 44 stations among the 174 remaining ones. Owing to favourable meteorological conditions, the initial goal was exceeded and 134 validated stations were finally sampled.

Table 1. *Nephrops* in the Bay of Biscay (VIIIab). Above: Landed and discarded weights since the DCF routinely conducted sampling onboard. Below: Discards and landings in numbers (10³ individuals) obtained by sampling onboard and at auction. Only years with sampling onboard are presented.

	Landings (1)					Total Discards	Catches
Year	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
2018	na	2038	86	na	2125	*1571*	*3696*
2019	na	2065	89	na	2154	634	2789

(1) WG estimates (2) landings from VIIIa and VIIIb aggregated until 1974 (3) outside FU 23-24

Italic font: revised value between WGBIE 2019 and 2020 (from 1627 t to 1571 t)

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
2018	151 926	83 463	65
2019	**59 102**	**96 919**	**38**

In 2020, LANGOLF-TV was carried out on 10 actual days (July 22nd-31st). The equipment (sledge, computing hardware, screens, recorders) were provided by the "Marine Institute". 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. As for 2019's survey, the new HD system CathX was adopted this year.

The reduction in the number of stations was based on the 2018 campaign (239 stations also including the area outside the benchmarked edge of the Central Mud Bank; 184 stations in the stock validated area and 55 elsewhere) as follows:

- 10 stations to zero burrows in 2018 and 2019
- 7 rocky stations in 2018
- 5 stations not validated in 2018
- 12 stations intentionally abandoned in 2018 on sandy areas with no appearance of burrows in previous years

- 31 stations outside the Benchmark 2016 framework
- 44 stations removed by random draw and including all strata

Acquiring images on the sea bottom requires a preliminary use of multi-beam 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. Recording lasts 10 min even with no *Nephrops* burrows on the track; 7 min minimum are necessary for the validation of the footage.

Up to 2019's survey, the provisional absence of reference footage in the Bay of Biscay implied 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. 4) allows to decide on the conformity or not of each reader. The delay of the survey in 2020 and the impossibility to read footage onboard induced lack of time between the end of the survey and the deadline for stock assessment and advice. There was additionally unavailability of sufficient experienced Ifremer agents having the readers agreement because of many other oceanographic surveys. As consequence of that, the recordings were read by only one person (8 minutes counted per station, 7 taken into account for processing) apart from 10 common stations. Accordingly to recommendations of the WGNEPS, all readings will be doubled before the next year's survey.

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]; 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}= total 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)[1] 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}.

[1] 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% for years 2014-2018 (but ≈5.5% in 2019 and ≈8.6% in 2020); thus, the stratified plan is further developed on only one sampling level.

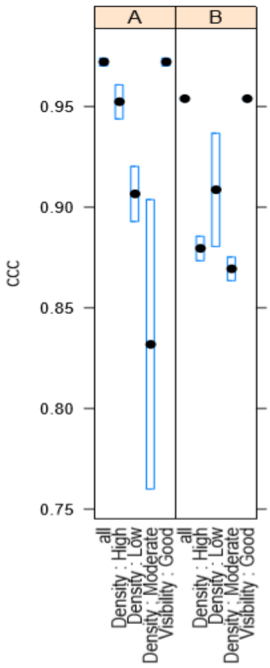

Figure 4. Conformity test CCC. 2020's results.

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 2016-2020, 100% of the Central Mud Bank was sampled (respectively 160, 94, 148, 116 and 117 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 whereas the additional sampling effort outside the edge in 2018 affected the sampling level in the 2016's benchmarked area in a lesser degree. In 2019, the sampling coverage was also impacted by the weather conditions. Table 2 shows results of raising of burrow densities (/m^2)[2] associated to their CVs by stratum for years 2014-2020. Results for 2020 show a steep decrease by -24% compared to 2019 (+18% between 2017 and 2018, +6% between 2018 and 2019).

Table 2. Total number of burrows (10^6), densities/m^2 and CVs by spatial stratum and for the whole area. Years 2014-2020 *(values not corrected by the cumulative bias factor).*

	2014 (156 stations)				*2015 (96 stations)*				*2016 (160 stations)*			
	nb/m²	total burrows	CV (%)	%burrows	nb/m²	total burrows	CV (%)	%burrows	nb/m²	total burrows	CV (%)	%burrows
	0.442	**5164.53**	**5.82**		**0.386**	**4501.89**	**8.25**		**0.386**	**4505.52**	**7.86**	
CB	0.317	802.68	15.68	15.54%	0.151	383.85	25.66	8.53%	0.258	654.41	19.84	14.52%
CL	0.171	196.72	28.30	3.81%	0.306	352.28	18.57	7.83%	0.237	272.72	20.87	6.05%
LI	0.354	1651.31	8.69	31.97%	0.320	1492.89	16.38	33.16%	0.283	1319.12	13.86	29.28%
VS	1.656	1048.72	11.05	20.31%	0.875	553.75	30.48	12.30%	0.839	531.18	17.92	11.79%
VV	0.544	1465.10	13.19	28.37%	0.639	1719.13	10.99	38.19%	0.642	1728.09	14.52	38.35%

	2017 (94 stations)				2018 (148 stations)				2019 (116 stations)			
	nb/m²	total burrows	CV (%)	%burrows	nb/m²	total burrows	CV (%)	%burrows	nb/m²	total burrows	CV (%)	%burrows
	0.303	**3534.20**	**9.85**		**0.357**	**4172.82**	**8.44**		**0.378**	**4413.87**	**8.59**	
CB	0.152	384.49	20.10	10.88%	0.259	656.93	19.56	15.74%	0.259	436.35	25.39	9.89%
CL	0.262	302.03	14.76	8.55%	0.517	595.61	23.64	14.27%	0.517	464.82	43.28	10.53%
LI	0.210	978.48	14.75	27.69%	0.228	1064.10	13.27	25.50%	0.228	1363.72	14.34	30.90%
VS	1.147	726.44	27.94	20.55%	0.841	532.43	23.30	12.76%	0.841	370.94	21.46	8.40%
VV	0.425	1142.76	19.82	32.33%	0.492	1323.75	17.30	31.72%	0.492	1778.04	12.12	40.28%

	2020 (117 stations)				
	nb/m²	total burrows	CV (%)	%burrows	% surf
	0.286	**3343.31**	**10.18**		
CB	0.072	182.34	24.46	5.45%	21.72%
CL	0.229	263.73	44.46	7.89%	9.87%
LI	0.195	911.55	18.76	27.26%	39.94%
VS	0.903	571.69	20.14	17.10%	5.42%
VV	0.525	1414.01	16.96	42.29%	23.05%

2. Raising including the rough sea bottom.

From 2016 supplementary area assumed to not be trawled as occupied by rough ground was also covered (Table 3). 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 3. Total number of burrows (10^6), densities/m² and CVs by spatial stratum and for the whole area. Years 2016-2020 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
	0.320	**5167.67**	**7.84**		**0.259**	**4181.95**	**9.87**		**0.291**	**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%
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%
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%
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%
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%
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%

	2019 (145 stations)				2020 (134 stations)					
	nb/m²	total burrows	CV (%)	%burrows	nb/m²	total burrows	CV (%)	%burrows		% surf
	0.316	**5100.64**	**8.34**		**0.263**	**4247.08**	**12.74**		-16.73%	
CB	0.172	436.35	25.39	8.55%	0.072	182.34	24.46	4.29%	-58.21%	15.69%
CL	0.403	464.82	43.28	9.11%	0.229	263.73	44.46	6.21%	-43.26%	7.13%
LI	0.292	1363.72	14.34	26.74%	0.195	911.55	18.76	21.46%	-33.16%	28.85%
VS	0.586	370.94	21.46	7.27%	0.903	571.69	20.14	13.46%	54.12%	3.92%
VV	0.661	1778.04	12.12	34.86%	0.525	1414.01	16.96	33.29%	-20.47%	16.65%
RO	0.153	686.77	28.17	13.46%	0.201	903.76	46.57	21.28%	31.60%	27.76%

As for the other raising options, the number of burrows seems to have steeply declined between 2016 and 2017 (-19%) then increased by +12% and +9% respectively in 2018 and 2019. In 2020, a reduction of –17% was observed. 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.

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 (relative precision≈11%). This value is still used for 2016-2020's data. The adoption of the HD system since 2019 suggests the necessity to update this coefficient.

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 colonise *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 2014-2020 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. 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. *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. The last two years reveal similar pattern for both crustaceans modelled according to Gauss curves (Figure. 6 and 7). The observed active individuals fluctuated a lot: for *Nephrops* in the range 235-1369 (minimum in 2019, 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 higher numbers apart from the three last years' surveys. 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. The combination of the correction factors above provides a cumulative bias coefficient of 1.24.

The advice 2021 for the stock was performed on the basis of the 2020's UWTV survey results corrected by the cumulative bias coefficient combined with the harvest rate for the year 2019 (LFDs and mean weights for landings and discards, discard survival rate fixed at 50% since the WKNephrops 2019 which revised the historical value of 30%) (Table 4).

Table 4. Catch option table for the FU23-24 Nephrops including information from the 2020's UWTV survey.

Variable	Value	Notes
Stock abundance (2021)	3425.061	Number of individuals (millions); UWTV Survey 2020
Mean weight in projected landings	23.82	Average 2017–2019; in grammes
Mean weight in projected discards	10.99	Average 2017–2019; in grammes
Projected discards	53.6	Average 2017–2019; percentage by number
Discard survival *	50	Percentage by number
Dead projected discards	37.4	Average 2017–2019; percentage by number

* *Only applied in scenarios where discarding is allowed.*

Catch scenarios assuming recent discard rates

Basis ***	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	Harvest rate * %	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD	for PL + PDD	
ICES advice basis							
MSY approach: F_{MSY}	6105	5044	3984	1060	1060	7.70	−7.1
Other scenarios							
F_{2019}	2438	2014	1591	423	423	3.07	−63
EU MAP ^: F_{MSY}	6105	5044	3984	1060	1060	7.70	−7.1

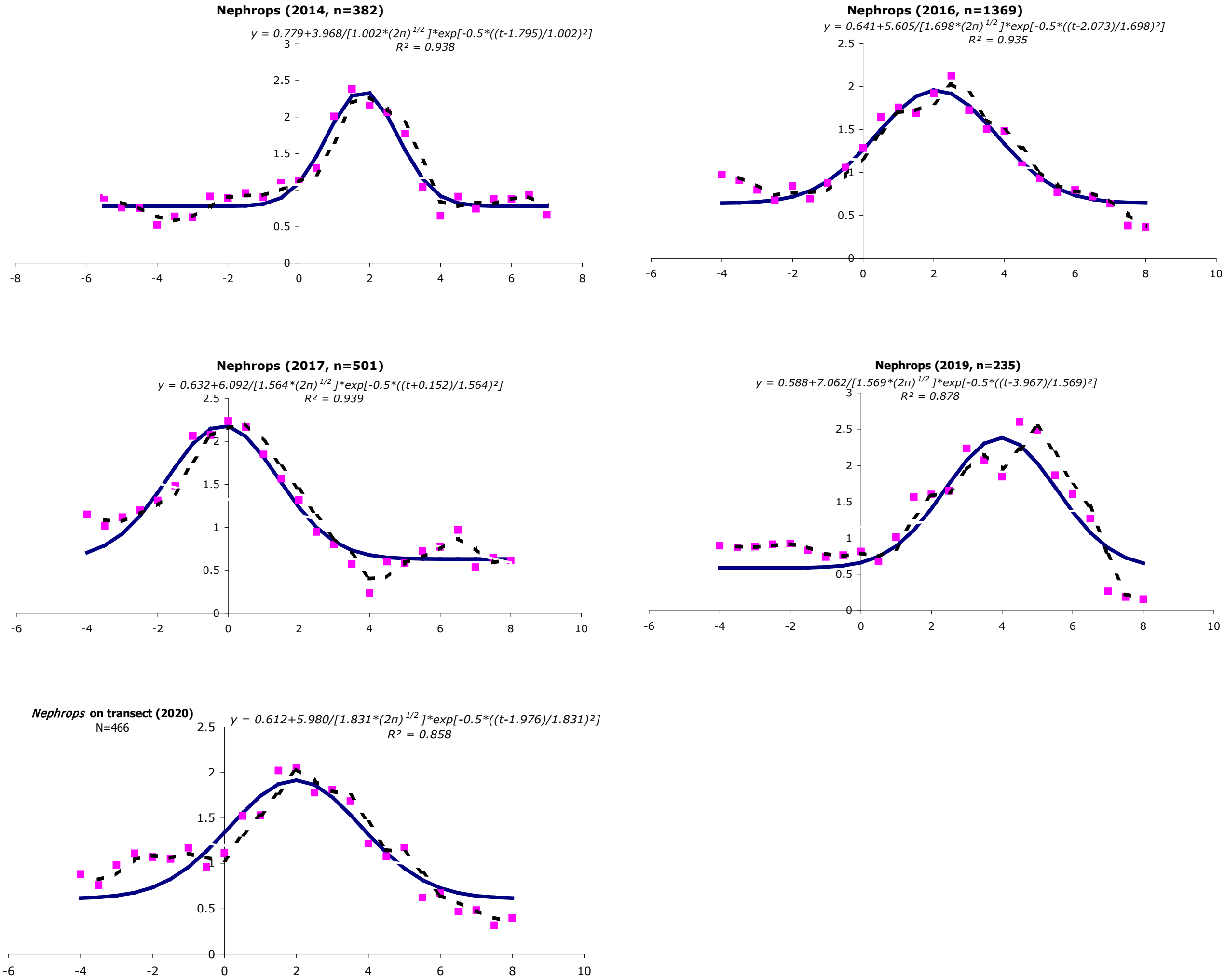

Figure 6. Relationship between standardised time of observation *vs.* sunrise/sunset and *Nephrops* activity for years with relevant pattern (2014, 2016, 2017, 2019 and 2020). Abundance index per surface unit of video track *(broken curve: data smoothed by mobile average).*

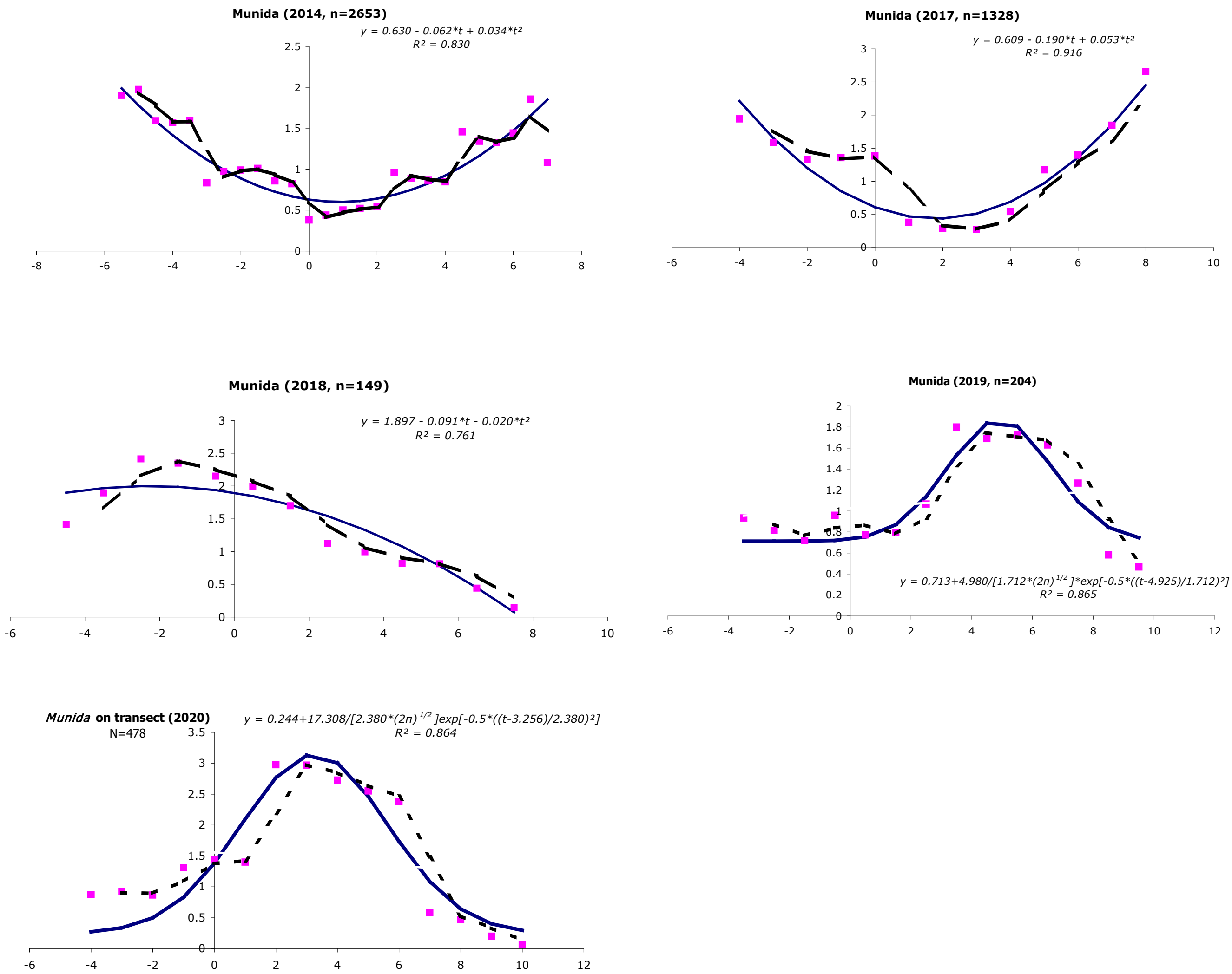

Figure 7. Relationship between standardised time of observation *vs.* sunrise/sunset and *Munida* activity for years with relevant pattern (2014, 2017-2020). Abundance index per surface unit of video track *(broken curve: data smoothed by mobile average).*

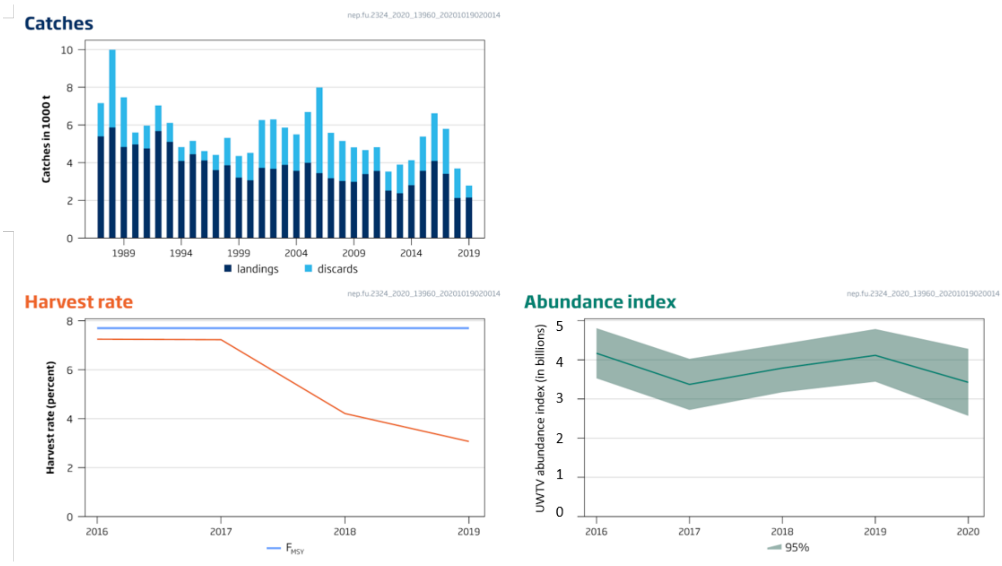

Figure 8. *Nephrops* FU2324 (Bay of Biscay). Standard graphs for the stock advice 2021.

Iceland FU 1: Off South Iceland

(Jónas Jónasson)

The fifth UWTV survey on *Nephrops* ground in Iceland was carried out by the Marine and Freshwater Research Institute (MFRI) between 10th – 19th of June 2020. The survey took place on RV Bjarni Sæmundsson. Like previous surveys it covered all known *Nephrops* ground in FU1.

Area definition was based on available AIS data (2008 – 2018). Vessel fishing with *Nephrops* trawl and at towing speed (1 – 4 nm) were summarised on grid with a resolution of 800 m. A minimum of five trawling occurrence was choosen as a threshold value for each area within the grid. Further the minimum size of each area was set as 4 km². In total 13 distinct fishing grounds were identified and further summarized to 9 areas (Figure 1). In total the *Nephrops* grounds in FU1 were estimated to be 6588 km² compared to 6353 km² based on VMS data from 2008-2017. The increase between years was mostly due to new fishing areas being exploited in south-western part of the grounds.

Stations were laid out in similar manner as previous years on a randomized fixed square grid with around 4.5 nautical miles between points, with in total of 84 stations completed. The depth of stations ranged from 100 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 and counted on each station. Vessel position and odometer on the sledge was used to estimate the distance overground (DOG).

All burrow system were timestamped in the inhouse image software Hafmynd, 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. From the UWTV footage, burrow system size, the occurrence of trawl marks, seapens, fish and other species, were also noted..

The mean burrow density (adjusted to account for bias factors) was 0.07 burrows per m² with CV of 7.1% (Figure. 1). The total number of burrows in 2020 was 450 million (adjusted values).

The total number of burrows in 2020 was 434 million (adjusted values). That is a decline from burrow count in 2019 which was 493 million (Figure. 2 and 3)).

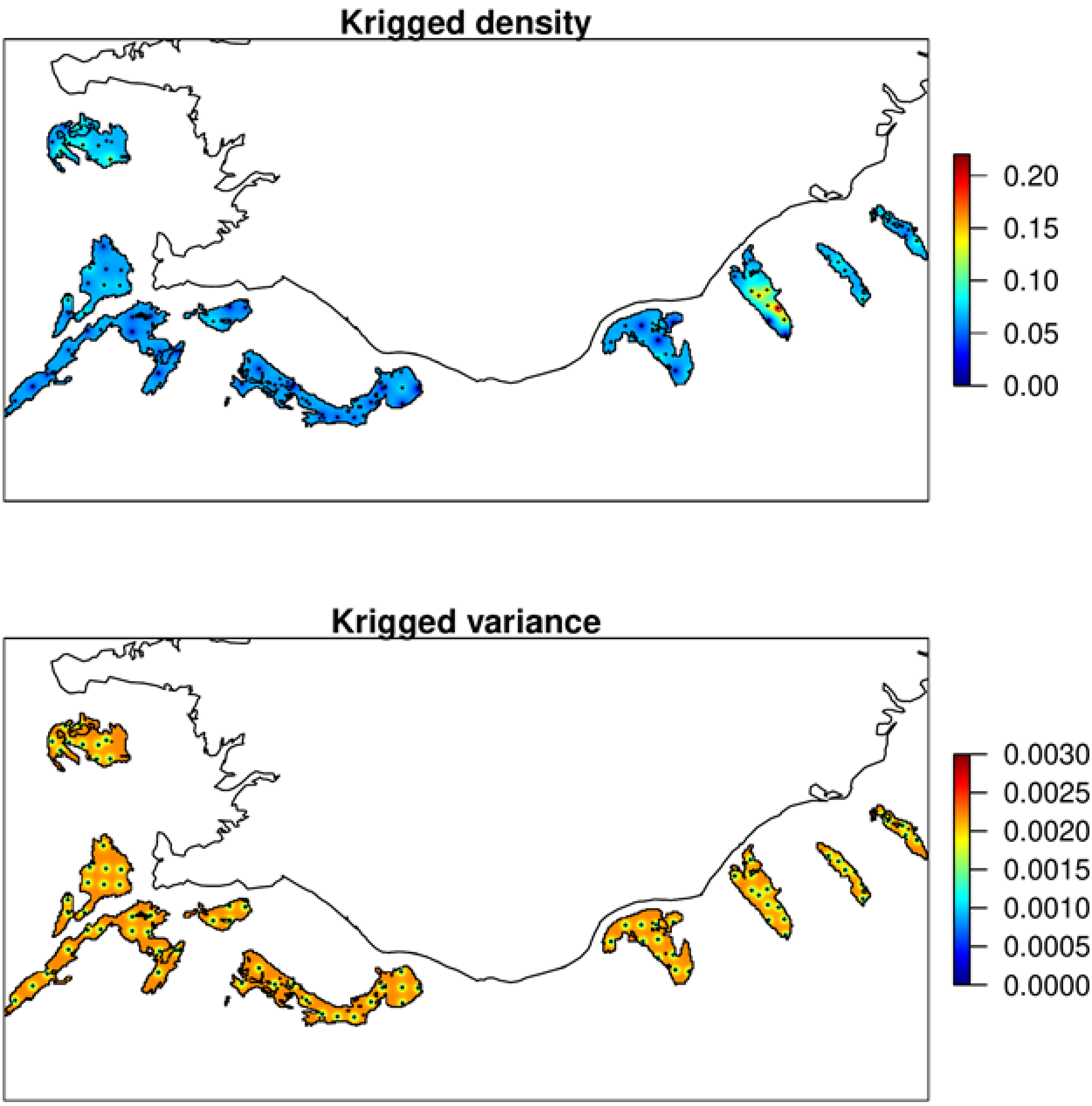

Figure 1. FU1 grounds: Contour plots of the krigged burrow density (per 100m²) estimates (above) and krigged variance (below), from the 2020 survey. Black crosses represent the stations.

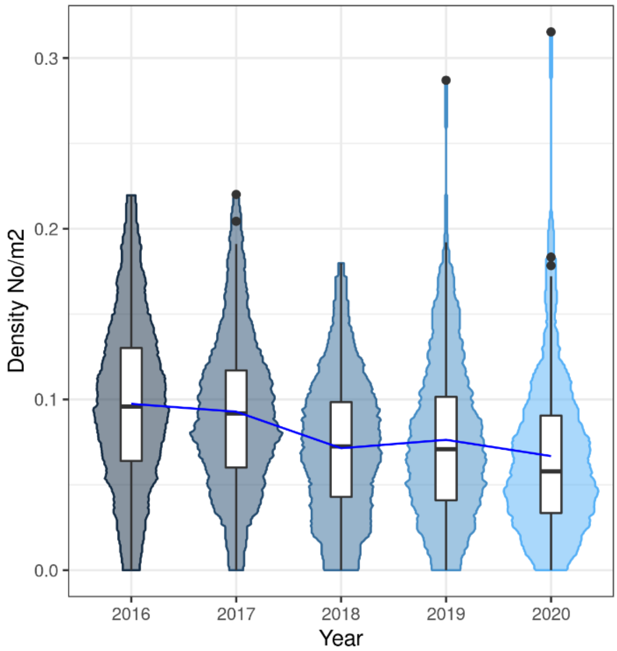

Figure 2. FU1 Iceland: Violin and box plot of adjusted burrow density distributions by year from 2016 - 2020. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

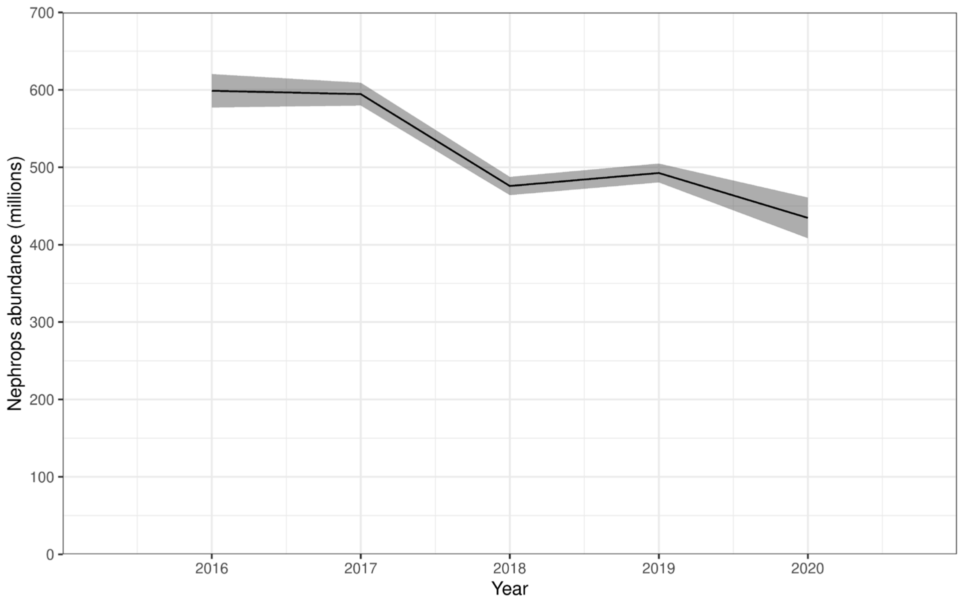

Figure 3. FU1 Iceland: Stock abundance (Underwater TV, millions; SSB proxy, 95% confidence intervals).

Italy and Croatia GSA 17 and 18: Adriatic Sea

Martinelli M., Medvešek D., Chiarini M., Angelini S., Belardinelli A., Caccamo G., Cacciamani R., Calì F., Canduci G., Croci C., Domenichetti F., Giuliani G., Grilli F., Guicciardi S., Penna P., Scarpini P., Santojanni A., Zacchetti L., Cvitanić R., Isajlovic I., Vrgoc N., Milone N., Arneri E.

The Pomo (or Jabuka) Pits area is one of the main fishing ground for Norway Lobster *Nephrops norvegicus* and European hake *Merluccius merluccius* within the GFCM Geographical Sub Areas 17 (Northern and Central Adriatic Sea) and it is shared by the Italian and the Croatian fleets (Russo et al. 2018). Furthermore, this represents a well-known nursery area for *M. merluccius* (Angelini et al. 2016) and hosts a distinct population of *N. norvegicus*, characterized by small-sized mature individuals (Froglia and Gramitto 1982; Vrgoć et al. 2004; Colella et al. 2018, Angelini et al. 2020). Due to a decline in landing of both species for the Adriatic Sea (FAO-GFCM 2019), since 2015 the Italian and the Croatian governments implemented some protection measures in that area. Eventually in 2018, the GFCM established a Fishery Restricted Area (FRA; GFCM 2017).

Although not covered by DCF, following early trials (Froglia et al. 1997; Morello et al. 2007) a spring UWTV survey is carried out since 2009 (except for 2011 and 2018) in the Pomo Pits by CNR-IRBIM of Ancona (formerly part of CNR-ISMAR), jointly with IOF of Split and under the auspices of the FAO – AdriaMed regional project (Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea; Martinelli et al. 2013). The latest equipment improvements are dated 2016 (Martinelli et al. 2016). The collected footage is usually analyzed later in the institute labs by a team composed by Italian and Croatian scientists, complying as much as possible with ICES standards (ICES 2017, ICES 2019) and applying some specific thresholds (e.g. on speed and turbidity) settled for the Adriatic footage (Martinelli et al. 2016; Martinelli et al. 2017a). Aiming to produce an index of abundance to use as tuning for a length-based integrated stock assessment model (CASAL; Bull et al. 2005), the Adriatic team is constantly working to address the uncertainties still linked to the application of this method within the study area; therefore in 2019 a complete revision of the time series 2012-2017 was carried out and presented at WGNEPS 2019 (ICES 2020). Unfortunately, due to the COVID-19 pandemic, the survey was not conducted in spring 2020.

Usually during the UWTV Adriatic surveys, along with CTD casts, trawl hauls are also carried out by means of an experimental net, at sunrise and sunset, in order to obtain demographic and biological data on *N. norvegicus* and other species relevant to the area (Martinelli et al. 2017a). Since 2015, an additional autumn trawl survey (using the same net and CTD) is carried out in the western side of the Pomo Pits area; the latter is planned in the framework of an agreement between the Italian Ministry of Agriculture and Forestry (MIPAAF) and CNR-IRBIM and aims to evaluate the effects of the management measures enforced in the area (Figure xx; Martinelli et al. 2017b).

Indeed, in 2018, these Adriatic surveys were included in the monitoring plan adopted by the Scientific Advisory Committee on Fisheries (GFCM-SAC) to monitor the Pomo FRA effectiveness.

The obtained catch per unit of effort (CPUEs) datasets were analysed in order to statistically detect possible effects of the Pomo FRA implementation on the main target species, in terms of biomass and distribution (Martinelli et al. 2019). The preliminary results were presented to the AdriaMed Working Group on Demersal Fisheries Resources (18 May 2020) and reported to MIPAAF (Martinelli et al. 2020), before upcoming submission to GFCM and publication.

Furthermore, aiming to use these CPUEs time series as input for stock assessment models, standardization exercises through generalized additive models (GAM) are in progress.

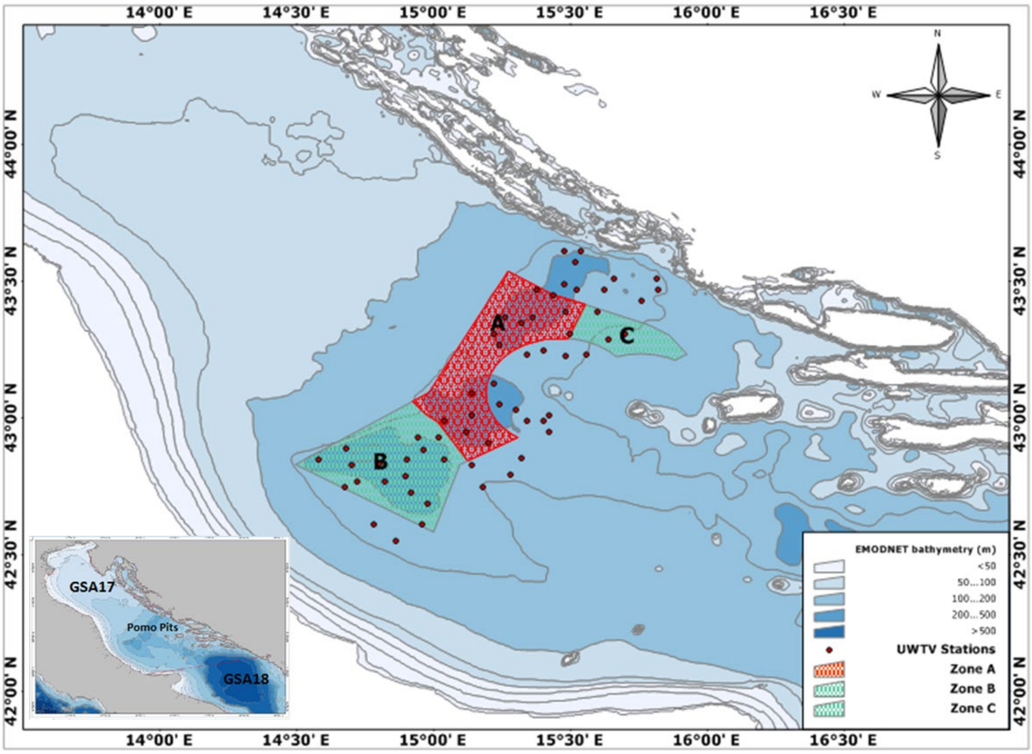

Figure 1. Pomo (Jabuka) Pits area within GSA 17 with indication of bathymetry (EMODNET bathymetry in meters), location of the UWTV stations (points) carried out during the spring surveys and FRA zones (zone A closed to any professional fishing activity, zones B and C subject to fisheries limitations; GFCM 2017).

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Annex 4: List of presentations

(in order of appearance)

Kai Wieland, Patrik Jonsson, Mats Ulmestrand, Sven Koppetsch, Annegrete Dreyer-Hansen, Maria Jarnum, Gert Holst, Ronny Sørensen, Baldvin Thorvaldsson, Anders Wernbo and Filip Bohlin: *Nephrops* UWTV survey in the Skagerrak and Kattegat (FU 3&4) in 2020. 11 pp.

Jennifer Doyle and Mikel Aristegui et al. : 2020 Update on Marine Institute Ireland *Nephrops* UWTV surveys. 24 pp.

Candelaria Burgos and Yolanda Vila: IEO Developments on the UWTV survey in the Gulf of Cadiz (FU 30) 2020. 18 pp.

Adrian Weetman: Marine Scotland Science 2020 UWTV surveys summary. 18 pp.

Jónas Páll Jónasson, Julian Burgos, Georg Haney, Arnþór Kristjánsson, Anna Ragnheiður Grétarsdóttir, Arnar Björnsson, Auður Bjarnadóttir & Hjalti Karlsson: Development of UWTV survey in Icelandic waters. 13 pp.

Martinelli M., Medvešek D., Angelini S., Belardinelli A., Caccamo G., Cacciamani R., Calì F., Canduci G., Chiarini M., Croci C., Domenichetti F., Giuliani G., Grilli F., Guicciardi S., Penna P., Scarpini P., Santojanni A., Zacchetti L., Cvitanić R., Isajlovic I., Vrgoc N., Milone N., Arneri E.: Adriatic UWTV surveys and Pomo monitoring activity. 16 pp.

Mathieu Lundy: AFBI Western Irish Sea *Nephrops* Grounds (FU15) 2020 UWTV Survey and Trawl survey. 19 pp.

Charlotte Reeve: CEFAS Survey results and assessment summary for FU 6 and FU14. 10 pp.

Spyros Fifas and Jean-Philippe Vacherot: Ifremer FU23-24 *Nephrops* Analysis of UWTV Survey 2020 results and overview of stock status and technical operations. 19 + 14 pp.

Julien Simon: Application of Neural Networks using Langolf Dataset. 28 pp.

Atif Naseer: *Nephrops* norwegicus detection and classification from underwater videos using deep neural network. 57 pp.

Jacopo Aguzzi and Bahamon Nixon et al. : Burrow emergence rhythms of *Nephrops norvegicus*, UWTV, surveying biases and novel technological scenarios, EMSO-Link Transnational Access (TNA) project SMARTLOBSTER 26 pp.

Ivan Masmitja, S. Gomariz, J. del Rio (UPC), J. Navarro, J. Aguzzi, M. Vigo, N. Bahamón, J. A. García, J. B. Company (ICM-CSIC): Acoustic tracking by networked moored hydrophones in *Nephrops* no take zones Deep NW Mediterranean. 29 pp.

Maria Vigo, Joan Navarro, José A. García, Jacopo Aguzzi, Guiomar Rotllan, Nixon Bahamón and Joan B. Company: ROV as a non-invasive tool for the assessment of an overexploited protected area in the Northwestern Mediterranean Sea. 19 pp.

Niall Fallon: *Nephrops norvegicus* abundance estimates bias and uncertainly FU 11 and FU 12. 23 pp.

Mikel Aristegui and Jennifer Doyle: MI High Definition reference set compilation 2020. 6 pp.

Mikel Aristegui: ToR c – Github WGNEPS. 3 pp.

Adrian Weetman: ToR b – Developing international database status and update and Nephrops FU and survey areas shapefiles. 1 pp.

Annex 5: Action list

	Action	Addressed to	Action latest before
1	Provide outstanding parts of the WG report	All WG members	At latest 17/12-2020
2	Review and comment on completed draft report	All WG members	At latest 15/1-2021
3	Conduct efforts to obtain burrow system size measurements	All WG members	01/11/2021
4	Have meeting with ICES database centre	One member per institute	At latest 18/12-2020
5	Follow up on meeting with ICES database centre on the UWTV database	One member per institute	17/11/2021
6	Check FU’s shapefiles and provide feedback to Rui Catarino at ICES	All WG member	asap
7	Contact end user for UWTV datasets feedback	Patrik, Ade	01/11/2021
8	Submit final version of SISP to TIMES committee and resolution	Jennifer	asap
9	Update/Upload R scripts for UWTV survey data analysis and quality control on github	All WG members	Ongoing
10	Develop reference sets for other FU’s and report to WGNEPS	National Institutes	Ongoing
11	Hold meeting with researchers to decide on best annotation tools to develop training sets	One member per institute /Jennifer	asap
12	Full review of 2020 FU23-24 UWTV survey data so that at least 2 readers counts per station in line with UWTV TIMES publication (in progress).	Ifremer	Before WGBIE 2021