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Report of the Workshop on *Nephrops* burrow counting

9-11 November 2016

Reykjavík, Iceland

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Executive summary

The Workshop on *Nephrops* burrow counting (WKNEPS), met in Reykjavik, Iceland on 9–11 November 2016. This meeting was chaired by Jennifer Doyle (Ireland) and included 17 participants from nine countries (Iceland, Ireland, UK-Scotland, UK-England and Wales, UK-Northern Ireland, Sweden, Spain, France and Croatia). In recent years new and developing surveys have been carried out on seven *Nephrops* grounds. The underwater TV survey footage from these grounds have different characteristics and can pose challenges for *Nephrops* burrow identification. The workshop was convened to address these challenges through building identification skills and support counting procedures for new and developing TV surveys and also to review footage of various *Nephrop*s grounds to check counting skills.

The group focused on three main areas:

1) the review of current status of available training materials and procedures;

2) the training of personnel in the complexities of burrow counting in different *Nephrops* grounds through group review sessions and

3) the production of reference counts for standardization of counter performance.

Training materials and procedures are well documented for institutes and follow good practice. There is a need to update the material (photo-guides, annotated footage training segments and reference footage) when changes to the *Nephrops* grounds occur and also when there are upgrades to the underwater TV sledge system.

Footage from several *Nephrops* grounds was available each with distinct characteristics and problems in interpretation. Plenary viewing of the footage helped consolidate a common consensus on burrow identification and video footage quality for speed, visual clarity and system set-up.

Reference footage from four main *Nephrops* grounds was available (Iceland, Kattegat, Gulf of Cadiz, and Pomo Pits - Adriatic sea). The reference footage was reviewed by national and international counters at the workshop where reference counts were completed for FU1 Iceland and for the remaining areas a task list for completion was agreed.

1 Terms of Reference

A Workshop on *Nephrops* burrow counting (WKNEPS) will meet in in Reykjavik, Iceland from 9 to 11 November 2016 (chair: Jennifer Doyle, Ireland) whose terms of reference are:

a) To build capacity on burrowing counting skills and support counting procedures for new surveys, at a European level.

b) To analyse challenges and differences among *Nephrops* grounds.

c) To update the SISP based on conclusions and redefine counting protocols if necessary.

d) To define periodicity of this type of training workshops.

2 Introduction

Nephrops stocks are divided into Functional Units/GSA for the purposes of assessment, the locations of which are shown in Figure 2.1. Regular underwater TV surveys are now scheduled in 21 FUs and 1 GSA with more intermittent data available from 3 further areas (Figure 2.1). In recent years new underwater TV surveys have been carried out on: FU16 (Porcupine Bank), FU20-21 (Labadie, Jones and Cockburn), FU23-24 (Bay of Biscay), FU30 (Gulf of Cadiz) and FU1 (Iceland), while developing surveys also occur in FU3-4 (Kattegat and Skagerrak) and Pomo Pits (GSA 17) *Nephrops* grounds. The UWTV survey methodology is by now well established and documented and the surveys are coordinated by the Working Group on *Nephrops* surveys WGNEPS (ICES, 2016). The first dedicated workshop on *Nephrops* burrow identification took place in Belfast (ICES, 2008) where the group consisted of mainly beginners to *Nephrops* burrow counting as well as more experienced scientists. Over the years "new" scientists have participated in established underwater TV surveys to train and bring these skills to their institutes, while experienced scientists have also joined new surveys as support. In addition a one day training session was scheduled during SGNEPS (ICES, 2010) to check counting skills.

However there is a continued need to broaden and develop *Nephrops* burrow identification skills within institutes and to have this peer reviewed. This workshop was convened to address this through building identification skills and support counting procedures for new and developing TV surveys and also to review footage of various *Nephrop*s grounds to check counting skills.

There were three main tasks for the workshop: (1) review of current status of available training materials and procedures and (2) to group review footage from national laboratories to and update the SISP if required and (3) to review reference footage sets for the developing surveys and where possible generate reference counts for these.

The first day was given to presentations first from each institute detailing the training materials and procedures used prior to counting survey footage and also during the review of survey footage. A comprehensive presentation on *Nephrops* burrow identification and signature burrow features was given in the afternoon and group discussed.

On day 2 and 3 there were two streams of work: review of reference footage sets by national and international counters to generate reference counts where possible focusing on four areas: FU1, FU3-4, FU30 and Pomo Pits. The remainder of the group reviewed footage from each survey area to check counting skills.

This workshop consisted of a significant proportion of experienced scientists in *Nephrops* burrow counting as well as less experienced scientists.

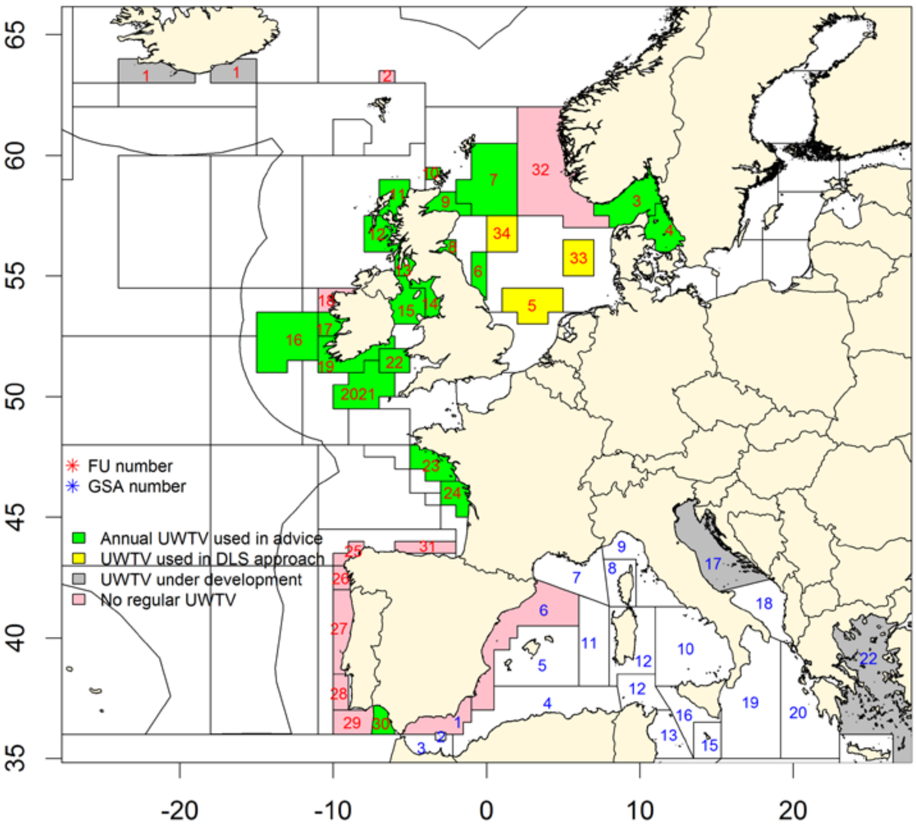

Figure 2.1. ***Nephrops*** **underwater TV survey coverage in 2016.**

3 Overview of standard Training Procedures

Training material and procedures in how to identify and count *Nephrops* burrows currently used were presented by each institute and discussed by the workshop. These are in line with recommendations from previous ICES meetings (WKNEPHBID: ICES, 2008, SGNEPS: ICES 2009 and 2010). Most institutes have the facility to review the footage during the survey whereas others review the survey footage back in the office post survey operations. Regardless of where footage review takes place there are common steps in the training procedures where counters undergo familiarisation using:

- Professor Jim Atkinson burrow presentation which was first presented at WKNEPHBID (ICES, 2008);
- In-house training presentation showing key burrow signature features and typical burrows of 'problem species' typical of the survey area;
- Review 1 minute video footage segments annotated or narrated as a group / in isolation.
- Review previous survey footage from the area as a group / in isolation.
- New counters are trained with experienced counters.
- Review reference footage to check

There are some differences that are in use such as: Marine Science Scotland circulates a DVD (containing approx. 6 UWTV stations) every 2 months so that staff refresh their identification skills regularly; Cefas have annotated 1 minute video segments for the Farn Deeps as part of their training process while AFBI and the Marine Institute also have narrated 3 x 1 minute segments for use in training.

Once training has been completed counters next review the reference footage set twice, independently and in isolation for a given survey area in order to validate their counts prior to counting the survey footage. Lin's concordance correlation coefficient (CCC) was first proposed at WKNEPHBID (ICES, 2008) to check counter performance against the reference counts. SGNEPS 2010 recommended that a minimum threshold of value 0.5 is used to assess if further training is required for individuals. Once the threshold has been passed counters may proceed to review the survey footage.

For new and developing surveys which do not have reference footage set such as FU23-24 and FU30 these institutes have used reference sets from other *Nephrops* grounds with similar densities to assess counter performance. For those surveys which cover multiple FUs such as those carried out by Scotland and Ireland, the survey counts for a specific area must be completed before the counting team can begin the reference footage review of the next area as each survey area has distinct characteristics.

For the Pomo Pits *Nephrops* underwater TV survey the team of scientists from both countries meet for one week post survey operations to train and then count the survey footage. The scientists use footage from survey year 2009 where Professor Jim Atkinson generated reference counts and also the most recent survey year where the equipment has been upgraded as training material.

The survey footage for the Skagerrak and Kattegat underwater TV survey (FU3-4) is reviewed back in the office post survey, where the Danish stations are reviewed by DTU and the Swedish stations by SLU. New counters have typically been trained by experienced counters where they have familiarised themselves by reviewing previous year's footage as well as reading through Professor Jim Atkinson training presentation. A workshop was held at DTU in 2014 where burrow counting experts from Cefas provided training exercises and material to help improve DTU and SLU counters' identification skills.

Standard procedures when counting survey footage are outlined in the SISP underwater TV Survey manual. These include details of how many minutes are to be counted from each TV station, warm-up session details, resume counting after a break details, where to count on the screen and removal of minute counts where footage quality deteriorates. Most institutes now follow these protocols. Once survey counts are completed, additional independent or consensus counting is used to correct discrepancies in counts. On an independent counting procedure the Lin's CCC test (with a minimum threshold of 0.5) is recommended to check which stations will need to be reviewed again and if a third or more counters need to be added. For some institutes if a counter is consistently falling below this independent check further training is given. For consensus counting of survey footage where there are discrepancies these group reviews are constructive to assess counter performance.

Annotation of *Nephrops* video footage

The ability to quickly and efficiently mark the positions of burrow systems on video footage would offer benefits not only for training purposes but also for allowing an efficient way to quality control and validate burrow counts. Such a tool would be of importance in high density areas where multiple burrow complexes are situated in close proximity to each other, where there may be greater discrepancies between burrow system counts.

Video editing software has previously been used to annotate footage and highlight the location and number of entrances to a burrow systems. FXHome Effects 2010 (FXHOME Ltd) was trialled by Cefas in 2010 (Figure 3.1) and whereas this software allowed annotation it was a laborious and challenging process which would not be feasible for the annotation of all burrow footage or even a reference set. Another video editing software, DebugMode Wax™ 2.0e, was also trialled Cefas but again this was found to be unsuitable. Further details of this software can be found in the report from WKNEPHBID (ICES, 2008).

As video editing software advances and file formats become less restrictive, the ability to annotate video footage quickly and easily with free or relatively cheap software will likely improve. The two editing software programmes suggested above are likely obsolete and an investigation into more advanced software packages should be carried out.

Figure 3.1 Screenshot of annotated *Nephrops norvegicus* burrow footage, with a three-entrance burrow complex highlighted in green.

4 Introduction to *Nephrops* Burrows Identification

Terminology

Terminology when describing *Nephrops* burrows needs to be set out as in the current literature it can vary somewhat and may cause confusion for the novice. The term entrance and opening are often used interchangeably and in this report it is recommended to use the term “burrow entrance”. As recommended by WKNEPHBID (ICES, 2008) it is better to use the term “burrow system” where a burrow system may be a single entrance or a multiple entrance system instead of the term “burrow complex”.

Juvenile burrow entrances

Nephrops are a mud burrowing crustacean that can be found at depths ranging between 7 m to around 900 m, at various locations as far north as Iceland and to the south, Spain; from the west of Ireland to Israel in the east. The consistency of the sediment in which they construct the subsurface systems can have different proportions of silt and clay, depending on the depth, hydrographic influences and bathymetry at these locations.

Once the *Nephrops* metamorphose to the post-larvae stage 6-8 weeks after hatching, they settle on the seabed, and providing the sediment is favourable and they survive the transition, the juvenile *Nephrops* begin to construct a burrow. This initial tunnel has a more vertical entrance than more established systems, appearing round, disk shaped on the seabed when viewed from above with a sledge or drop frame camera system. Juvenile burrows tend to be found in close proximity to adult systems (Marrs *et al.*, 1996) where some burrow systems are conjunctions of the tunnels of adults and one or more juveniles and such burrows should be counted as a single burrow system. Sometimes the characteristics of the juvenile burrow entrance tend not to be typical in identifying *Nephrops* systems and therefore these are either not recognized or ignored.

Structure of the burrow entrance

As the *Nephrops* extend the linear burrow, the entrance of the burrow tends to become eroded in line with the direction of the burrow as the animal frequently enters and exits the system with excavated material. This results in two characteristics that are key to identifying *Nephrops* burrows. The main identifying feature of an adult *Nephrops* burrow is the crescent shaped entrance. Whereas most other burrowing species in the same environment, as well as juvenile *Nephrops*, burrow vertically creating a circular entrance, entrances created by *Nephrops* are angular, becoming shallower over time. As the observation platform (sledge, drop frame etc.) passes over these entrances a distinct crescent shape is observed, enhanced by the shadows generated by the lighting used in UWTV system. The second feature in identifying *Nephrops* burrow entrances is the excavated material that is constantly being removed from the system in order to keep the system well maintained, or in the process of expanding the system. This discarded material is dragged and/or pushed out of the entrance and deposited immediately at the mouth of the entrance. Over time this material is spread out to avoid a large spoil heap at the burrow entrance and in doing so creates a fan or delta shaped feature. On occasion track marks can be observed emanating out from the mouth of the entrance over the delta, formed by the chelipeds and perieopods of the *Nephrops*. In addition, the excavated material can appear a different colour to the surrounding sediment, especially if freshly exposed to the surface or removed from the burrow shortly after a mass settlement of fauna such as an algae bloom die-off. Figure 4.1 shows the main signature features of a *Nephrops* burrow entrance.

Linear burrow system

Over time the initial is burrow lengthened and eventually emerges some distance away from the original entrance. Depending on sediment type and population density the two openings can be separated anywhere between only a few centimetres to over a metre with the system reaching depths of around 30 cm below the surface. The second entrance, or exit, mirrors the original entrance with a crescent shaped upper portion of the entrance and a developing delta of excavated material. Figure 4.2 is a resin cast of a linear system with scale bar of 25 cm. The third key feature to recognize in this situation is that the apexes of each of the crescent shapes of the entrances are facing each other, which is unique to *Nephrops*. Figure 4.3 shows the surface features of a linear burrow system.

Simple T-shaped burrow system

Providing the *Nephrops* has not succumbed and there are no other limiting factors, the system will be developed further and a second tunnel added to the original linear, U-shaped system. Evidence from resin casts clearly show that this additional tunnel will be constructed at 90° to the original tunnel forming a 'T' shaped system. The new branch of the system tends to meet at the midpoint of the original burrow. This new section also has a similar entrance to the two existing entrances, however the apex of this entrance's crescent points towards where the two tunnels meet. Figure 4.4 is a photograph of a resin cast of a simple T-shaped burrow system of two tunnels and three surface openings. Figure 4.5 shows the surface features of the simple T-shaped burrow system from UWTV footage.

Complex T-shaped burrow system

Further tunnels associated with the system can be developed over time, each having an entrance as previously described. But unlike the arrangement of first three entrances which follow a recognizable and standard pattern, tunnel length and burrow location in relation to the original T shape system becomes asymmetrical from the fourth entrance and beyond. These burrows can appear at any angle to and any distance from the original system. Figure 4.6 shows a resin cast of complex T-shaped burrow system showing branching tunnels and several surface entrances. Figure 4.7 shows the surface features of a complex T-shaped burrow system from UWTV footage. The defining feature of such complex systems is that all the apexes point to the centre of the system where the T-shape was formed while each entrance still has the same characteristics of the original *Nephrops* burrow entrance.

This highlights a major consideration when reviewing footage for *Nephrops* abundance: in that, only systems are counted and not individual burrow entrances. The counter is first identifying which entrances are *Nephrops*, then looking for clusters of entrances that appear to be related depending on burrow size and apex orientation and next to count these groups of related entrances as individual burrow systems.

Other burrow dwelling species

The main cause of confusion in correctly identifying *Nephrops* burrows is caused by burrow entrances created by other burrowing fauna. There are a small number of other burrowing species that have angled entrances or with deltas of excavated material, but these systems tend to have other features not associated with *Nephrops* (Marrs *et al.*, 1996). These species and their burrows have been described in detail where they are known and a key is available as a guide (ICES, 2017 Annex 6; ICES, 2008 Annex 5). For example the burrows of *Calocaris macandreae* (a mud burrowing shrimp species) are abundant particularly in the softer muds in the middle of the western Irish Sea grounds (FU15). These burrows entrances are circular and have a vertical drop. This can lead to confusion with *Nephrops* burrows for the novice counter. However, such allocation errors are minimized due to the training procedures employed prior to and during the survey. These include refresher training on classical *Nephrops* burrow signatures and consistency verification with reference count analyses. Figure 4.8 is an example of *Calocaris* burrows observed on the footage in this area.

Collapsed or "inactive" burrows

If a system is not well maintained in time it will collapse. This could be due to the animal having been removed from the system, for example from trawling or through natural mortality. The entrances of recently vacated systems no longer tend to be smooth, as the sediment from the apex slowly falls into the mouth of the burrow. Over time as more of the apex collapses, the roof of the entrance tracks away from the original site of the opening, regressing further towards the centre of the burrow and the other burrow entrance. Occasionally the centre of the system collapses leaving a furrow with shadows of the opposing entrances at either end. As the system is no longer inhabited, a system showing these features should not be counted. On larger more established systems, the size of the system may well be too great for the single *Nephrop*s to maintain and so some sections of the system may collapse yet other sections may well still be inhabited. Therefore a system where the path of a number of apexes converge on one central point, yet part of the system has collapsed (frequently the original burrow), is still deemed suitable to count. Still images in Figure 4.9 shows collapsed burrow entrances.

Recently trawled ground

Areas that have recently been trawled also disfigure burrow entrances. Once the turbid water has cleared, typically two features provide evidence of trawling activity: a deep trench where the otter board/trawl door has ploughed through the sediment; and the more prevalent but much shallower, parallel grooves where the trawl's bobbins (or disks) on the groundrope have swept the area. Trawls can either push sediment into burrow entrances or slice off the surface sediment, but either way this transforms to a greater or lesser degree of how the burrow entrances appear. Figure 4.10 is an image of trawled ground with slight striations with a linear burrow system.

Species presence in a burrow entrance

Occasionally the presence of species in burrow entrances may cause some confusion. For example the presence of a squat lobster in a burrow entrance with signature *Nephrops* burrow characteristics should not result in discounting this as a *Nephrops* burrow system. The presence of *Nephrops* in a burrow entrance as a sole feature for identification also requires due caution as the animal may not be the architect.

In summary the main characteristics defining an active *Nephrops* burrow system are:

- a crescent shaped entrance
- a delta of excavated material
- where visible the angle of descent is shallow
- the apexes of the entrances facing each other in a simple U-shaped system
- or converging on one central point in a more developed system; several entrances forming a T-shape in some systems

Due to the equipment used in viewing the seabed, the orientation of the burrow in relation to the camera or local variations in the sediment type or density, whether the ground has been recently trawled not all of these characteristics maybe be present or observed.

Figure 4.1. Image from UWTV footage of the surface features of a burrow entrance. Crescent shaped entrance with driveway or delta of sediment from excavation, angle of descent is shallow where visible and tracks maybe present also. © Cefas (left image), MSS (right image).

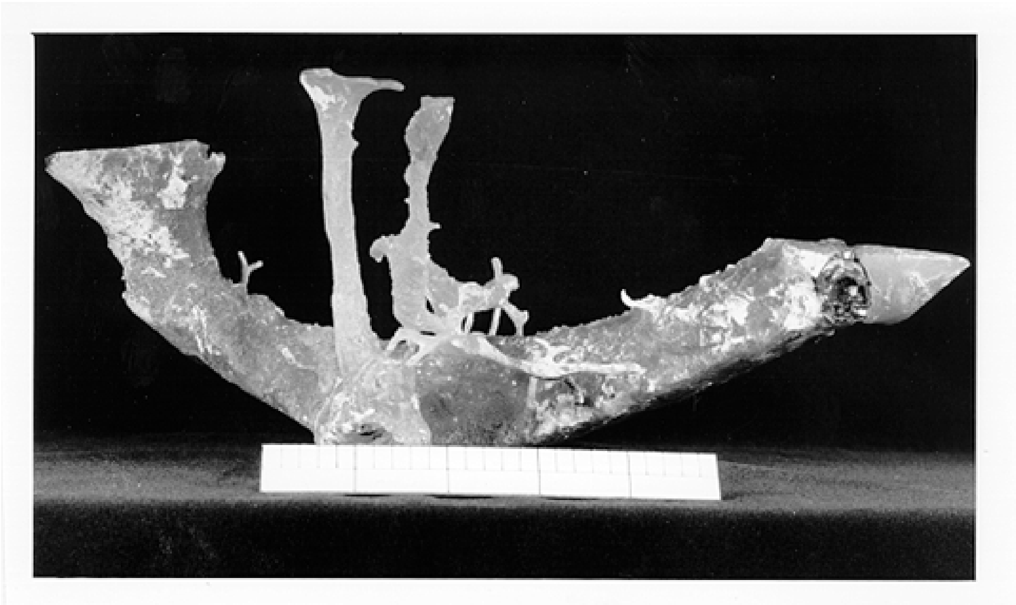

Figure 4.2. Resin cast of a linear burrow system with two entrances with 25 cm scale bar. © MSS.

Figure 4.3. Image from UWTV footage of surface features of a linear burrow system. Crescent shaped entrance with driveway or delta of sediment from excavation. The apex of the two entrances are facing each other so this is counted as one system with two entrances. © MSS.

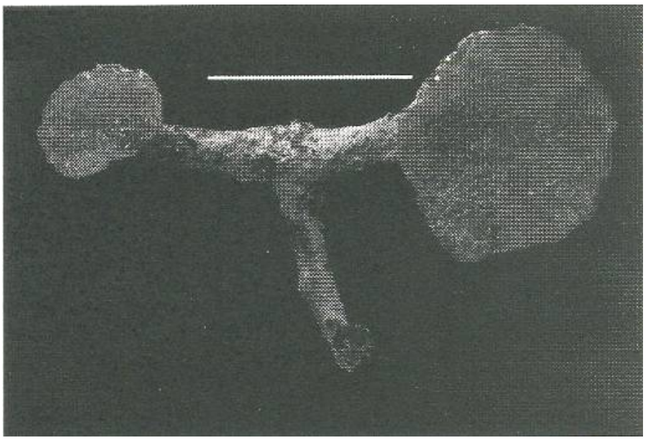

Figure 4.4. Resin cast of a simple T-shaped burrow system with scale bar length 20 cm. © Marrs *et al.,* 1996.

Figure 4.5. Image from UWTV footage of a simple T-shaped burrow system. © Cefas.

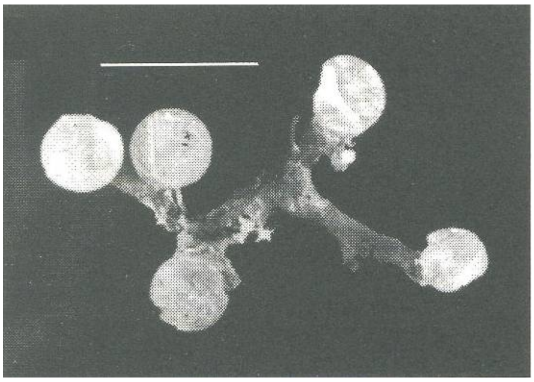

Figure 4.6. Resin cast of a complex T-shaped burrow system 5 entrances. Scale bar length 20 cm. © Marrs *et al.,* 1996.

Figure 4.7. Image from UWTV footage of a complex T-shaped burrow system. © MSS.

Figure 4.8. Image from UWTV footage in FU15 showing *Calocaris macandreae* burrow entrances which are circular shaped and angle of descent is vertical. © Jim Atkinson.

Figure 4.9. Images from UWTV footage showing collapsed or "inactive" burrow entrances where sediment is filled in at the entrance. © MSS.

Figure 4.10. Image from UWTV footage of a linear burrow system with some slight trawl marks visible with striations running southwest to northeast. © Marine Institute.

5 Creation of Reference Sets and Generating Reference Counts

Prior to the workshop reference sets for new and developing surveys were produced FU1, FU3-4 - Kattegat, FU30, FU7 and Pomo Pits in line with the recommendations from WKNEPHBID (ICES, 2008) as detailed below:

Reference Footage Sets

1. Each institute should produce reference sets of video footage comprising 10 runs of 5 minutes, with footage selected to cover the range of visibility (poor, medium and good), *Nephrops* density (low, medium and high) and species complexes likely to be encountered in each area. Each institute should collate video footage from their archives. The reference sets are to be made available to all institutes on completion in either DVD format (with each run comprising a separate chapter) or media file format such as mp4. Stations are to be titled 1 through 10.

2. The reference set should reflect the current survey conditions and ground characteristics.

Most of the national reference counts were generated prior to the meeting (FU1, FU3-4 and Pomo pits). The general practice was to have an international review of the reference sets independently during the workshop with updates to the group if needed.

The following summarizes the reviews of each survey area:

FU1 Iceland

The first UWTV survey was carried out in FU1 between 7 and 16 June 2016 following procedures from other areas. A reference footage set was generated from this survey as there was 100% coverage of the grounds. The visual clarity ranged from medium to good and the speed was usually around 1 nm/hour. Ten stations, distributed on most of the discrete grounds where chosen as the reference set (Figure 5.1). There are few known burrowing megafauna of concern in this region other than the crab *Geryon trispinosus*. The footage was shot with HD camera (Kongsberg OE14-502F) and video files are saved as MPEG and are around 1.6 GB in size. Each video was timestamped, with information on speed, depth, distance covered by wheel and how much cable is out. Snapshot examples of the reference footage are shown in Figures 5.2 and 5.3.

The counts for the area were less than 15 systems per minute, and the reference set had on average 4 systems per minute (range: 1.2–7.0). To generate the reference counts, four national counters and one experienced counter from Ireland viewed the footage. The reference set was timestamped by individual counters independently. Once the counts were completed the results compared and footage was reviewed in a group and counts agreed on if there were any discrepancies. Table 5.1 shows the time-stamps for a reference station from FU1. The reference counts were then finalized for this area at the workshop.

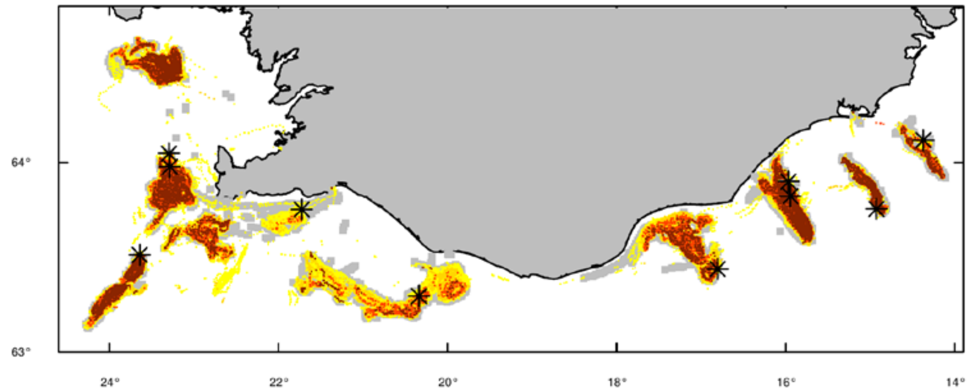

Figure 5.1. Overview of the reference footage stations (black asterisk) in FU1. Electronic logbook data are also plotted with colours ranging from grey/yellow to red-brown, or low or to high cumulative yield.

Figure 5.2. Snapshot from FU1 ground with a *Nephrops* burrow visible. The distance between the lasers (green dots) is 0.95 metre.

Figure 5.3. Snapshot from FU1 ground. The distance between the lasers (green dots) is 0.95 metre.

Table 5.1. Example from one reference stations in FU1 showing timestamped counts.

Station	Minute	count	Timestamp and Position	Comments
B10-2016-st.581	0	7	5R/ 8C-10C/20C/22C/28C/44R/54L	51R not counted
	1	6	6R-8L/27R-28L/33CL-37L/38R/44C/52R	27-28 counted as complex
	2	5	20L/26L-C/33C/38R/39R	
	3	5	27L/28C/29L/45R/48C	38 not counted
	4	6	2R/5C/15L/26C/49C/53R	

Pomo Pits – GSA 17 Adriatic Sea

The reference sets produced for the Pomo Pits area consist of five by ten minute sets recorded with the latest instruments setup. The footage is typical for this area and comprises different bathymetric strata. The speed of the footage is average (it strongly depends on the boat characteristics and weather conditions), and does not exceed 1.2 knots (threshold recently applied to the national dataset for acceptance: 1.38 knots). The visual clarity for all the reference footage was classified as good to very good (with turbidity lower than 1.5 nephelometric Turbidity Units (NTU); threshold recently applied to the national dataset for acceptance: 3 NTU). The files were saved in AVI format in five 2.2 GB large files. National counts were available for all of the footage including four annotated minutes of different stations. The national counts were generated as an average of five readers. The counts have been conducted independently and in case of high differences between readers the counts were repeated twice. In order to keep a high level in training for Adriatic readers the two national labs should keep reference sets up to date whenever a change is made in equipment or its assembly to the sledge.

The Pomo Pits area is characterized mainly by very small *Nephrops* individuals and with very high densities. Figure 5.4. is a screen grab of typical footage from this area showing many small burrows. In addition in this area there are very high densities of other burrowing species which makes the counting challenging for readers. Due to some technical difficulties during the workshop the time for the readers to familiarize with the footage was insufficient to finalize the international counts for the Pomo Pit area. However, a significant effort has been made by the groups most experienced readers to find a consensus in identifying the *Nephrops* burrows in this difficult area. It has been agreed that the footage should be reviewed by these readers with experience in high densities areas with more time to adjust to the specifics of this footage in their laboratories.

Figure 5.4. Snap shot from Pomo Pits video footage showing small burrows. Distance between stripe lasers is 0.80 metre.

FU30 Gulf of Cadiz

ISUNEPCA TV survey is annually carried out in the Gulf of Cadiz (FU30) since 2014. Until now, Porcupine Bank (FU16) reference footage has been used for the training prior to the surveys. For the workshop, a set of 10 x 5 minute footage segments was selected from 2015 and 2016 TV surveys in order to create the reference footage for this FU. Footage from FU30 was obtained with a Full HD camera and stored in an external hard disk in MOV format, with a size of around 460 KB per file. MAGIX Video deluxe 2015 software ® was used to create 5 minutes segments from the original 10 minutes videos, (MP4 format, approx. 700 KB).

Reference footage was independently counted and timestamped once by two national and one international counters during the workshop. These raw counts were then compared. Figure 5.5 shows the counts of the 3 counters for 5 reference stations. Results showed different trends between counters with a large variation in the range of counts. The international count was much higher than the national counts. Lin's CCC statistical test was used to check counter performance using a threshold of 0.5. Figure 5.6 shows the Lin's output plots for station 4 reference counts where counter 1 and 2 were scored high compared to pairwise plots for counters 1 to 3. Table 5.2 show Lin's CCC results between counters for the 5 video lines. The highest values were obtained for the national counters (counter 1 and counter 2) in n°4 video line (Lin's CCC = 0.8) followed by n°1 video line (Lin's CCC = 0.51) but Lin's CCC test failed in the rest of the video lines. Lin's CCC values obtained when comparing counts international and national counters were very low ranging between 0.06 and -0.07.

The variability of the counts can be explained by a number of factors. First the quality of the reference set stations were not all of "good" quality with visual clarity. Second, the counters found the time-stamping exercise was challenging as this was a new counting method for them. Lastly, challenges with the identification of small burrow systems illustrating the difficult nature of the footage in this area. A large proportion of small burrows systems were identified by the international counter whereas the national counts were much more conservative. The *Nephrops* ground in the Gulf of Cadiz presents areas with much bioturbation where a large number of burrows are found; many of them are small in size and built by both *Nephrops* and other burrowing fauna such as squat lobster (see Figure 5.7).

While the reference counts were not completed during this workshop the scientists involved agreed a workplan to achieve this in the next year: national scientists will establish a criteria on which "type" of small burrow systems should be counted as *Nephrops* given the difficult nature of the footage and a photographic document will be developed to illustrate this; and to ensure all footage in the reference set is of sufficient "good" quality (in terms of visual clarity).

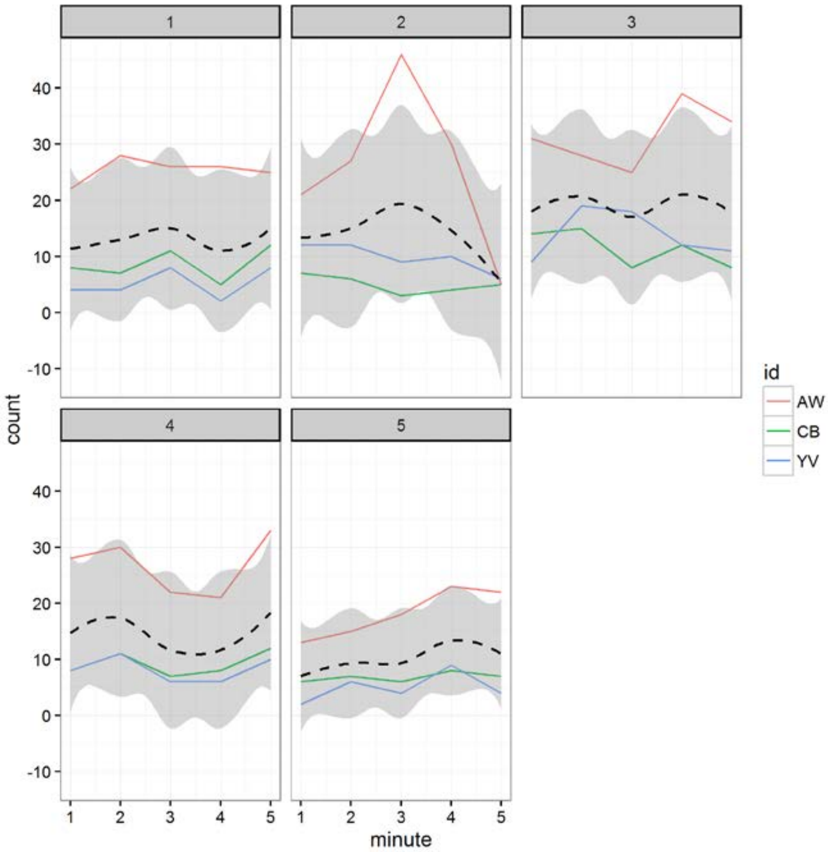

Figure 5.5. Counts of the 3 counters for 5 stations of the FU30 reference set.

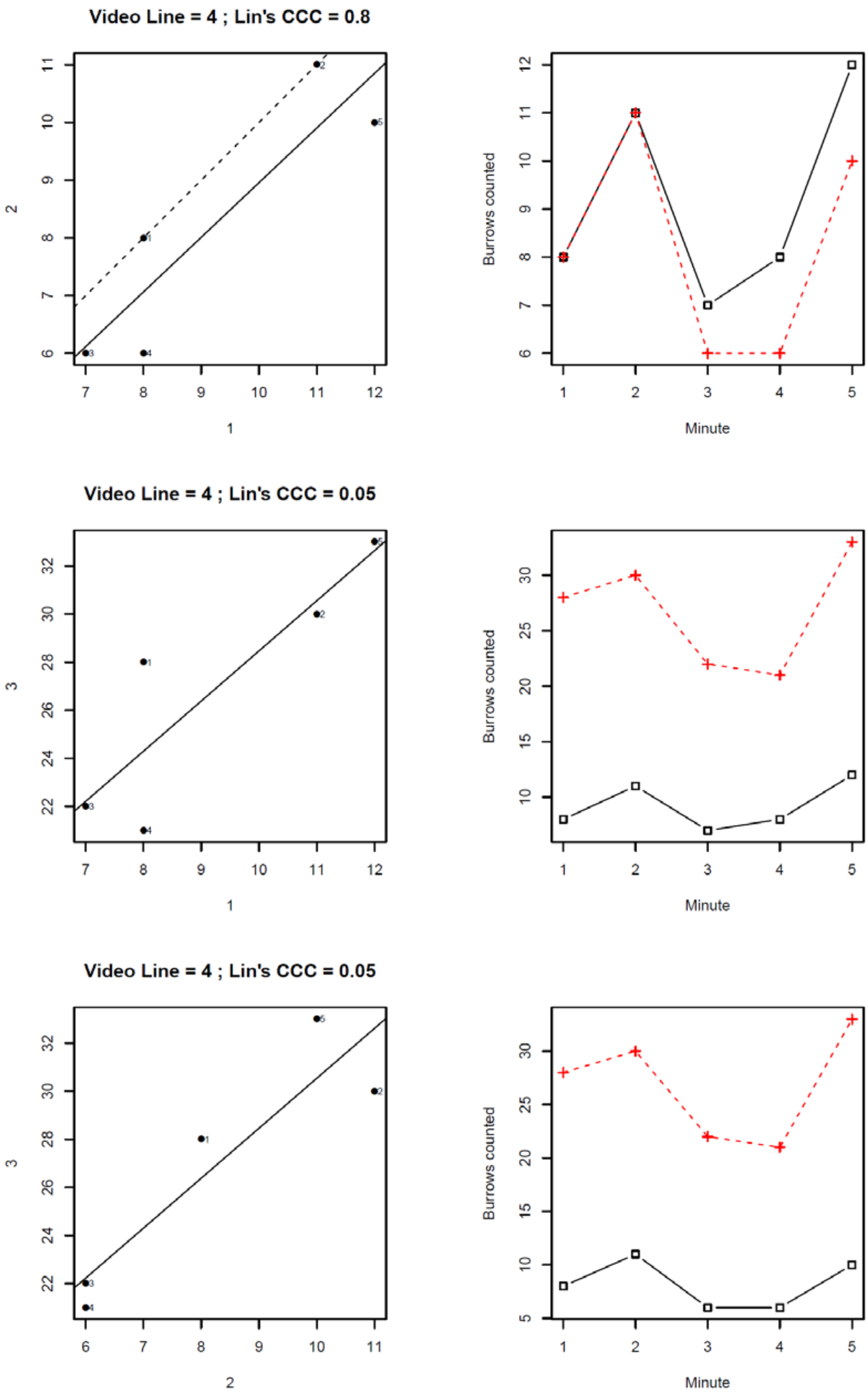

Figure 5.6. Lin's CCC plot of station 4 counts of FU30 reference set.

Figure 5.7. Screen grabs showing small burrow systems from FU30 video footage. Distance between stripe lasers is 0.75 metre.

Table 5.2. Lin's CCC values for five stations of the FU30 reference set.

Video Line	Counter1	Counter2	Lin's CCC
5	2	3	0.06
5	1	3	0.03
5	1	2	0.34
4	2	3	0.05
4	1	3	0.05
4	1	2	0.8
3	2	3	-0.07
3	1	3	0
3	1	2	0.01
2	2	3	0.05
2	1	3	-0.03
2	1	2	0.11
1	2	3	0
1	1	3	-0.01
1	1	2	0.51

FU3–4

At WKNEPHBID 2008 it was decided that a reference set should be comprised of 10 stations of 5 minutes and covering the range of usable video footage encountered on a typical survey. The selected stations should consist of different water qualities (clear to murky waters); high to low densities; and if available a mix of *Nephrops* and other species burrows.

A selection of stations from the 2015 Danish UWTV survey which adhered to the requirements outlined in the WKNEPHBID 2008 report were collated for a workshop. The workshop was held in Lysekil, Sweden 21–23 September 2016 where the most experienced counters from each of the two institutes – SLU (Sweden) and DTU Aqua (Denmark) created the reference counts for FU3-4. The chosen stations consisted of 4 high density (of varying visual clarity; 2 stations good, 1 station ok, and 1 poor visual clarity), 3 moderate density, and 3 low density stations (Tables 5.3 and 5.4). As standard practice, *Nephrops* burrow counts were recorded for each minute of each station.

Table 5.3. Station numbers assigned to different burrow densities (high to low densities) and water qualities (clear to murky video).

	Water quality				
		Good		Medium	Bad
Burrows	**High**	1033	1051	1086	2017
	Medium	1065		1144	1025
	Low	7016		5001	1004

Table 5.4. Station numbers assigned to each run.

Run	Burrows	Water quality	St. number	Start time	End time
1	low	good	7016	6:04:00	6:09:00
2	medium	good	1065	11:17:00	11:22:00
3	low	medium	5001	8:04:00	8:09:00
4	low	bad	1004	4:54:00	4:59:00
5	medium	medium	1144	8:53:00	8:58:00
6	high	good	1033	15:50:00	15:55:00
7	high	medium	1086	13:54:00	13:59:00
8	medium	bad	1025	7:11:00	7:16:00
9	high	bad	2017	6:53:00	6:58:00
10	high	good	1051	15:10:00	15:15:00

Each counter reviewed all the footage in isolation and only once all the reference sets had been reviewed were the results compared. The counts for FU3-4 were compared following the same principles outlined for other functional units (Fladen and Farn Deeps (FU7 and FU6 respectively).

Where differences between the counters reached a set threshold the footage for that minute was re-examined and a consensus between the counters was reached for that particular minute. The acceptance criterion for FU3-4 was as follows:

- Reference count of greater than 20 burrows per minute, counts more than 10% different from the mean were deemed unacceptable.
- Reference counts between 15 and 20 the criteria used was 20%
- Reference counts between 9 and 14 the criteria was 30%
- Reference counts for 8 or less it was 40%
- For all average counts of 1 or less it was decided there needed to be exact consensus.

The differences in the initial individual counts obtained for each of the stations was above the defined threshold for all bar one station (Table 5.5). Therefore, the four counters reread the reference material defining how to identify *Nephrops* burrows (WKNEPBID, 2008) and then reread all stations. The reference counts for each station were taken as an average per minute of the four counters.

Table 5.5. Initial counts (average number of burrows per minute) by station (10 x 5 minute run per FU) and counter. National counts only.

Functional Unit 3 and 4						
Station	Counter 1	Counter 2	Counter 3	Counter 4	Consensus count	Difference (%)
1	2.6	3.8	1.8	1.8	2.5	80
2	6	7.4	3.8	4.8	5.5	65
3	3	4.2	0.6	1	2.2	164
4	7.2	6.2	2.4	1.2	4.3	141
5	6	7	1.8	3	4.5	117
6	12	17.6	12.4	15	14.3	39
7	11.8	11.6	11.4	11	11.5	7
8	5.6	7.8	4.4	4.2	5.5	65
9	20.4	17.8	26.8	24.4	22.4	40
10	9.6	12.8	9.4	10	10.5	33

Table 5.6. Average counts (number of burrows per minute) by station (10 x 5 minute run per FU) and counter. National counts only.

Functional Unit 3 and 4						
Station	Counter 1	Counter 2	Counter 3	Counter 4	Consensus count	Difference (%)
1	2	2	1.8	1.8	1.9	11
2	4.8	4.8	4.6	4.6	4.7	4
3	1	0.8	0.8	0.8	0.9	24
4	1.8	0.6	1.2	1	1.2	104
5	3.8	3.4	2.8	3.4	3.4	30
6	13	12.8	12.8	13	12.9	2
7	11.8	11.6	11.4	11	11.5	7
8	4.4	4.2	4.2	4.2	4.3	5
9	32	31.8	32	31.4	31.8	2
10	10.8	10	10	9.8	10.2	10

Figure 5.8. shows the counts by station and minute for all four counters for the first (top panel) and second run (bottom panel) of the reference set. The Swedish counts were higher than the Danish counts for most of the stations. Also for most of the stations except station 7 there was a large spread in the range of counts. This prompted group discussions on burrows that were causing difficulty and the group reviewed footage together to discuss the footage. The reference footage is collated from Danish footage only so this could explain the differences in the counts. For run 2 (bottom panel)consensus counts it is clear that the group discussions have minimized counting errors as the counts are quite tightly grouped compared to the first run (top panel). Figure 5.9 is a boxplot of the first run (not agreed) and second run (consensus) counts by station shows that the maximum range for the majority of the second run data are

much less than those of the first run. The median value is also slightly lower in the second run dataset.

International counts were generated independently and in isolation twice during the workshop. The international counts from an experienced counter were compared to the national counts only after the second run was completed. The international count was generally higher for most of the reference stations. There were 3 stations which had the biggest variation. Figure 5.10 shows that stations 3, 8, and 9 where international counts was not in line with national counts. These stations were then reviewed and discussed by the international and national counter. For station 8 and 9 it was decided that as the footage quality was deemed "poor" due to newly trawled stations it would be better to remove these stations and choose additional material of better quality to complete the reference set. This is to ensure that counters are being checked on their performance using best quality footage which is the priority for underwater TV surveys.

Another issue that arose from the international review was the stripe laser appears to bend around burrow entrances in low density footage when there are undulations in the mud. This has not been observed previously and it was decided by the Workshop that the standard procedure for counting burrow systems in FU3-4 needs to address this. Screen grab images taken from reference footage during the workshop shows the issue of the laser bending close to burrows and when to count or not to count in these cases (Figure 5.11–5.14).

Lin's CCC analysis was carried out on the second run of the reference set using the consensus national counts and raw international count. Using a threshold of 0.5 which is routine on UWTV surveys two stations failed: station 3 and 8. Table 5.7 shows the Lin's CCC score for the failed stations. Lin's CCC performance check could be used to decide whether stations need a consensus count and this needs.

In summary the reference counts could not be finalized for FU3-4 at the workshop.

The group recommends that:

- the first count of the reference set by participants is a familiarisation and training exercise and is essential to the process of generating reference counts.
- the stations of poor quality be replaced with better footage quality (visual clarity and ground contact) and similar density grouping
- that all the national counters are trained as to when to include or not include burrows that fall on the "bending" stripe laser line and the national lab standard operating procedure, training material be updated to include clear examples of these cases.
- Once these issues are finalized the reference counts can be generated by each national lab in-house and the footage circulated to an international lab to count so that the reference counts can be calculated in advance of the next survey counting season.

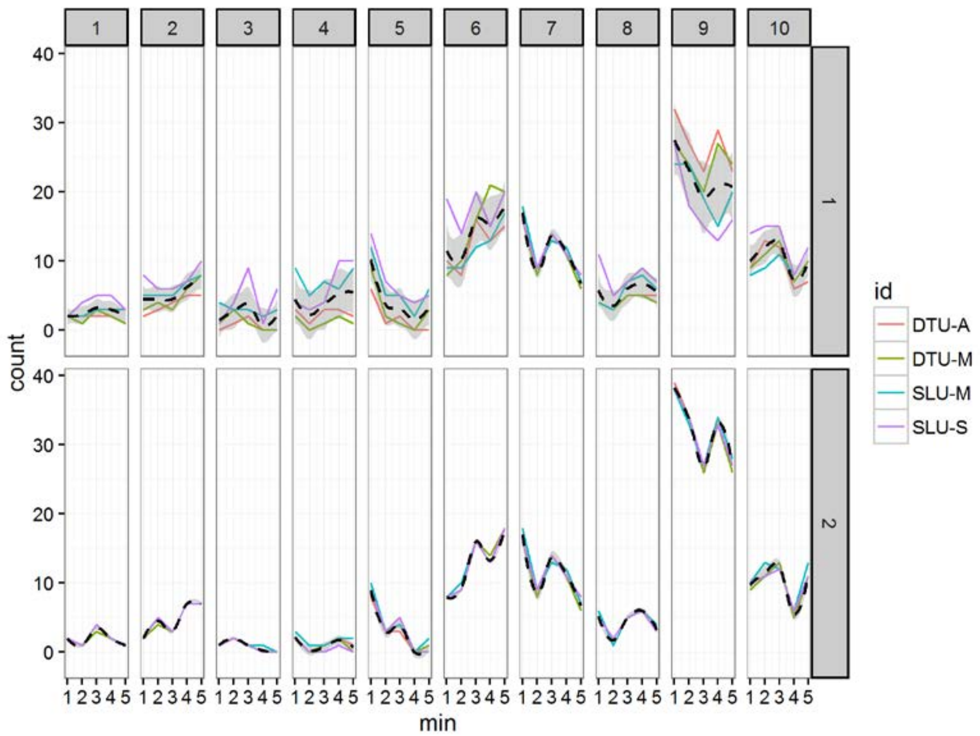

Figure 5.8. FU3-4: Top panel: Individual counts (not agreed) by minute and station for the first run. Bottom panel: consensus counts by minute and station for the second run with a loess smoother (dashed line).National counts only.

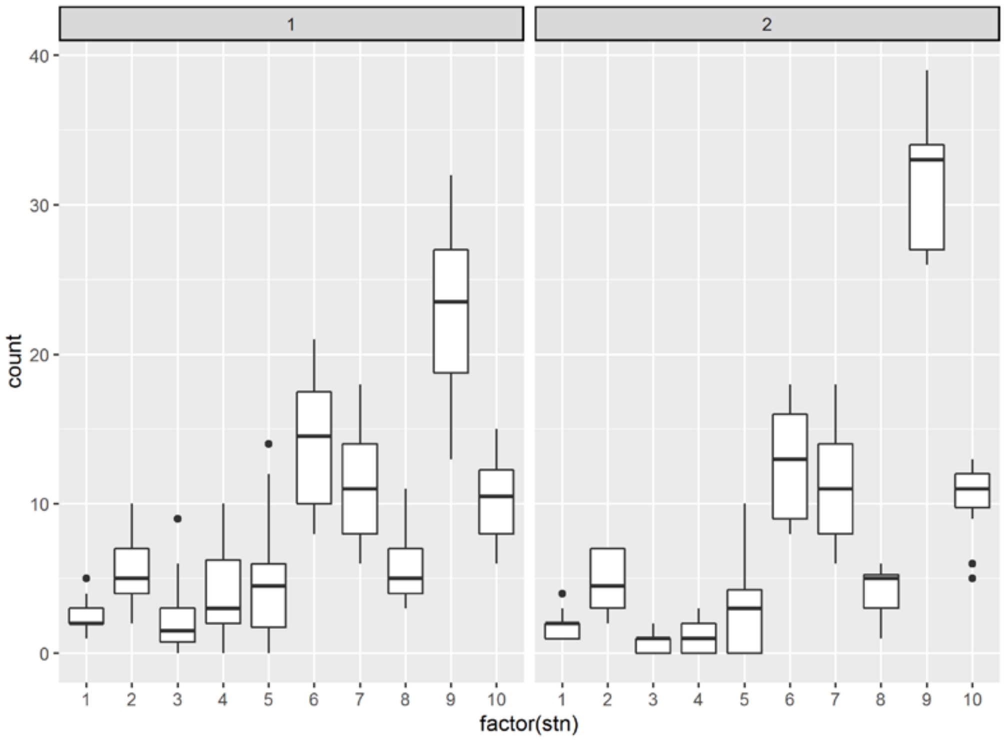

Figure 5.9. FU3-4: Left panel: counts (not agreed) by station for the first run. Right panel: consensus counts by station for the second run. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. National Counts only.

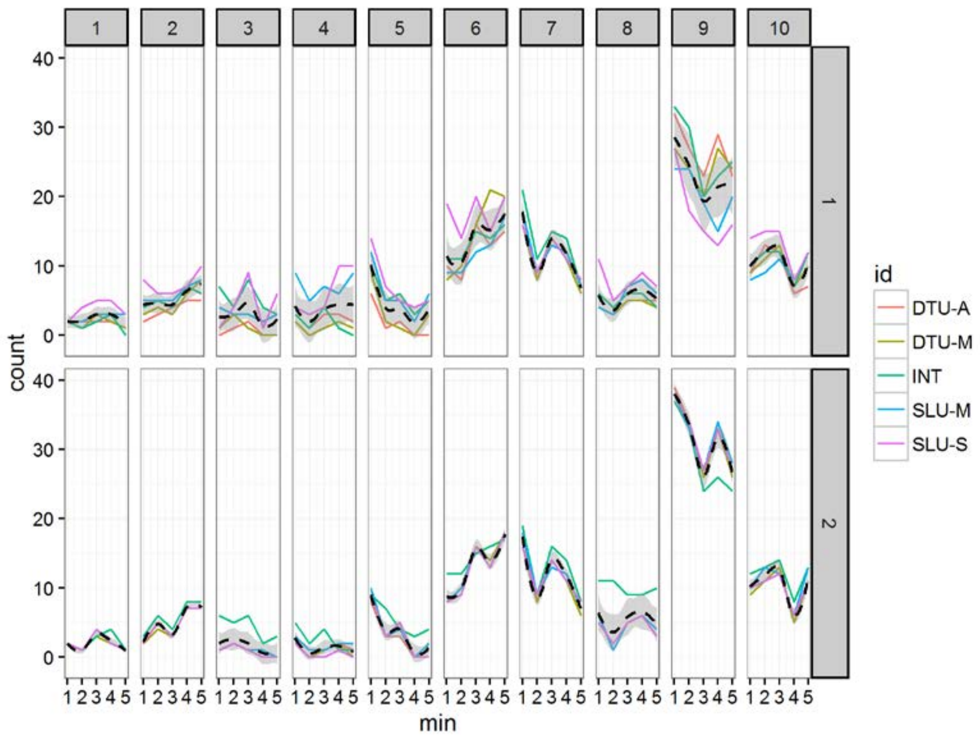

Figure 5.10. FU3-4: Top panel: Individual counts (not agreed) by minute and station for the first run. Bottom panel: consensus national counts by minute and station for the second run with a loess smoother (dashed line).International count (green line) and not agreed for this exercise.

Station	Counter 1	Counter 2	Lin's CCC
8	4	6	-0.04
8	3	6	-0.04
8	2	6	-0.04
8	1	6	-0.04
3	4	6	0.11
3	3	6	0.11
3	2	6	0.11
3	1	6	0.05

Table 5.7. FU3-4: Lin's CCC scores for stations that fell below 0.5 threshold.

Figure 5.11. FU3-4: Still image of video footage showing the misinterpretation where the stripe laser appears to bend around burrows. In this case the burrow on the right hand side is not counted.

Figure 5.12. FU3-4: Still image of video footage showing the misinterpretation where the stripe laser appears to bend around burrows. In this case the burrow on the far right hand side is not counted.

Figure 5.13. FU3-4: Still image of video footage showing the misinterpretation where the stripe laser appears to bend around burrows. In this case the burrow on the far right hand side is counted.

Figure 5.14. FU3-4: Still image of video footage showing the misinterpretation where the stripe laser appears to bend around burrows. In this case the burrow on the far right hand side is counted. Laser appears to dip inside the burrow.

6 Footage Review Groups

Training of existing and new counters was carried out where each institute presented footage from their survey area. The general practice was to review a small section of footage, commentating on what was being observed, and then to run several minute-by-minute counts to see how people were performing. When large discrepancies were observed further discussion around the rationale behind "accepted" counts ensued to harmonize the search pattern of counters. A general comment from the workshop is that the quality of the footage has an effect on counter confidence and ability to count. When collecting video footage: speed, ground contact by the sledge, lighting set-up, visual clarity needs to be constantly reviewed to ensure best quality data are collected for review.

The following summarizes the reviews of each survey area:

FU1 : Icelandic *Nephrops* grounds

High definition footage format. Burrows were easy to identify and count as low density and footage quality good in sledge speed, ground contact, and visual clarity. The workshop proposed that the survey counts should be timestamped given the small numbers where this is the practice for FU16 survey footage where counts generally <15 burrows per minute.

FU6 : Farn Deeps

High definition footage. Inshore area with many smaller burrow systems. Footage of good quality and relatively easy to identify count burrows.

FU7 : Fladen ground

Composite video format. Footage of good quality with low density and relatively to count.

FU12 : South Minch

Composite video format. This ground was "pock" marked with lots of small *Nephrops* burrows. Counters not familiar with this ground were very conservative initially but then counting agreement improved as they gained confidence with familiarisation.

FU3-4 : Skagerrak and Kattegat

High definition format. Footage from the Danish TV survey presented was considered to be easy to count as burrow counts were low and burrow structures clear. There was the issue of the stripe laser that seemed to "bend" in or around burrows. This had not been observed previously by the group. The workshop proposed that screen grabs of these be collated into a photo guide on how to count burrows in or out of the field of view in these situations. Also the workshop commented that the set-up needs some fine tuning where camera housing was in view and this can cause distractions.

FU20-21: Labadie, Jones and Cockburn Banks

Composite video format. Footage from this area showed a lot of variation in the seabed with undulations and sand waves. Footage is challenging to count given the changes in seabed and counters need some time to familiarise. Recommended that an international count to

FU23-24: Bay of Biscay

Composite video format. Footage presented to group was very high density >30 burrows per minute of small *Nephrops* burrow systems and possible *Munida* species interactions. Footage quality was good in ground contact and visual clarity but speed was sometimes fast and this needs to be considered when collecting the video data.

FU15: western Irish Sea

Composite video format. High density footage footage with *Calocaris macandreae* interactions. Quality of footage presented was good in speed and ground contact. Counters were in agreement with high counts for footage presented.

FU16: Porcupine Banks

Composite video format. Low density footage with large burrow systems. Quality of footage presented was good in speed and ground contact. Some footage was jumpy due to swell conditions.

FU30: Gulf of Cadiz.

High definition footage. Footage with lots of small burrow systems that presented a challenge to the counters.

Pomo Pits: Adriatic.

Composite video format. High density footage with multiple species interactions. Similar to footage from FU15. Quality of the video needs to be considered as speed can be fast.

7 Recommendations

The workshop made the following recommendations in these areas:

Training material

1. Training material needs to be updated regularly so that photo guides of "problem" species can be developed using screen grabs of survey footage (or photographs) for a given survey area.
2. Each national laboratory to create their own in-house guide in line with the SISP section on training material.
3. Training material is to include annotated 1 minute segments where software to do this should be investigated.

Reference footage sets and generating reference counts

4. Reference set to be updated set every time there is a change in gear set up (e.g. field of view, camera position, lasers, major changing in lights, new sledge etc.) or any major change on the ground (e.g. major changes on topography, change of population structure reflected by burrow systems size).
5. Reference footage to be of sufficient quality in speed, ground contact and visual clarity to assess counter performance.
6. Reference footage for areas FU3-4, FU30, FU7, FU14 and Pomo Pits to be circulated in early 2017 to allow international counts to be completed in advance of 2017 survey season.
7. For collaborative surveys reference sets to represent the complete survey area.
8. Each national laboratory holds a complete set of reference sets and therefore as each new reference set is generated it is distributed to the *Nephrops* coordinator at each laboratory.

Staff and Protocol exchange

9. WKNEPS recommends staff and protocol exchange between institutes.
10. WKNEPS recommends for collaborative surveys such as those covering FU14 and FU15 staff exchange should occur annually onboard.
11. WKNEPS recommends for those collaborative surveys where it is not possible to have staff exchange on-board it is recommended that a minimum of 15% of stations is reviewed by each participating institute.
12. WKNEPS recommends as a minimum there needs to be at least three experienced counters based in each institute.

Burrow counting workshop

13. Next burrow counting workshop to be held in 2018. Terms of reference and venue to be agreed at WGNEPS 2017.

8 References

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Annex 1: List of participants

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Annex 2: Agenda and List of Presentations

***Nephrop*s Burrow Identification and Training Workshop**

WKNEPS 2016, Iceland

There will be two main streams to the workshop: group reviews of footage from national labs and generating reference footage**.**

National footage for Group Reviews

Each national lab to present footage of 5–6 stations :1 x high, 1 x moderate and 1 x low densities and also 2–3 stations where counters find it difficult due to species interactions for their FU survey area. These 5–6 stations to be of good quality in visibility and good ground contact (10 minutes).

We intend to run Lin's CCC analysis on national footage in review groups so that we have outputs for the reports.

Please also bring any Lin's CCC plots or other quality control plots for these 5-6 stations that you may have.

As these stations will be from surveys which you have already reviewed and counted can you bring the CCC plots, QC plots and count data for these.

For those labs which have multiple survey FUs please bring material from areas which cause most difficulty but of course we will endeavour to get through as many as we can.

For example Ireland will present footage from FU16, FU20-21, and FU 22.

Reference footage for generating reference counts.

For those national lab who want to generate reference counts at the workshop please collate reference footage as follows as this process was last agreed at WKNEPHBID (ICES, 2008):

To collate reference footage.

At WKNEPHBID (ICES, 2008) - reference set was first discussed and counts generated at that meeting for FU6, 7, and 15.

"It was decided that a reference set would comprise of 10 stations of 5 minutes covering the range of usable video footage encountered on a typical survey. The range needed to cover clear to murky video; high to low densities; and if available a mix of *Nephrops* and other species burrows. Each institute collated video footage from their archives and burnt them onto DVD with each run comprising a separate chapter."

(For those labs who have high definition camera footage DVDs are not required).

For example Ireland have previously collated 4 high density (of varying visual clarity but 2 stations good with one ok to poor), 4 moderate density, 3 low density (whatever that means for your area and the usual visual clarity that you typically encounter on your survey).

If there are other species that make burrows such as crabs, calocaris or squat lobsters or other unknown burrowing benthic fauna you would also need to include that in the test.

Reference footage needs to be of good quality (visual clarity and ground contact) and there is no point in having all excellent visual clarity but neither is it correct to have a lot of very poor footage quality as this is not what we want to base our counts on for calculating the abundance estimate from the TV surveys. It is *usuable footage* typically encountered on the survey.

Name the reference stations 1–10.

To count reference footage

Follow the usual training documents/manual/SISP you have and also Jim Atkinson's power point on burrow structures (Annex 5).

Standard procedure on what to count and how to count (bottom edge of screen and edge effects) and assigning entrances to systems.

National labs would need a training set of 10 x 1 minute footage segments covering range of useable footage.

Is it very useful to have also 3/10 of these 1 minute training segments annotated as to where the burrows are – (time stamp these if possible).

We find this very useful as starting point from going from zero counting to counting 1 minute segments and then counting 5 minutes of reference stations.

1. Go through presentations on burrows, read annex 5 of WKNEPHBID
2. Each counter to count the 10 x 1 minute segments. Is very useful to have also 3/10 annotated as to where the burrows are.
3. Once the counters have performed well against the 10 x 1 minute segments they then can start the reference set.
4. Two national counters to read the set - independently and blind - counts only.
5. Third counter to be international and assigned at the workshop in Iceland.
6. Suggest that in the absence of annotating footage that each counter would timestamp the burrows they are counting. This will make review of reference footage simpler at workshop.

See datasheet attached for how to timestamp.

Each national lab participant to bring:

- National footage
- Reference footage if relevant
- Laptop with count data, qc plots.
- Please also have on laptop the following R packages installed to run Lin's CCC.
- Lin's CCC analysis code will be provided to the group.

RStudio	library(knitr)
library("epiR")	library(ggplot2)
library("reshape2")	library(lubridate)
library("mapplots")	library(tidyr)
library("shapefiles")	library(readxl)
library("gridExtra")	library("lme4")
library(dplyr)	library(RODBC)

Wednesday Day 1

9:30 – 11:30 Introduction by Chair (JD) and adopt of ToRs.

Introduction to *Nephrops* Burrows.

What to count? *Nephrops* burrows, how to identify and how to count *Nephrops* burrows? Presentation by Ade Weetman on *Nephrops* signature features, field of view, partial burrows.

Group discussion of counting protocol in relation to SISP document.

Review of training material.

Brief presentation by each national labs of training materials and formats currently in use. This presentation review of training procedures by each lab should be a 5 minute long with 1-2 slides maximum if possible. This presentation should include information such as is there annotated segments available for training, photo guide on burrows signatures etc.

10-11

Presentations by national labs (MI-Ireland, UK-Scotland, UK-England, Northern Ireland, Denmark, Sweden, IEO - Cadiz, Ifremer - Lorient, Italy-Croatia, Iceland, Greece?).

Group discussion of general training material in relation to SISP document.

12:00 – 13:00

Discussion of quality control of counts during a survey or back in the laboratory in relation to SISP such as:

- use of Lin's CCC to quality control the count data
- time-stamping burrow systems or other annotation of footage
- threshold for screening for deviations between counters

14:00- 17:30

Reference Count Sets.

Generate reference footage for areas – decide on international reviewers for reference sets. Assign reviewers and quiet rooms.

- FU1, Jonas
- FU3-4, Jordan, Mats, Kai
- FU30, Yolanda
- Italy, Michela
- FU14 (mini ref set, 5 stations – if there is enough time)

- Scotland FU7 (if there is enough time)

Group reviews of National footage.

Review national footage where there are 3 groups of 4-5 maximum where each group would discuss footage in detail. These 3 group sessions will run in parallel for duration of workshop.

Assign participants into 3 groups each with a group leader:

- Irish Sea Group (FU14 - FU15, GS- Adriatic Grounds, FU23-24 –Bay of Biscay)
- North Sea group (England, Scotland, Denmark, Sweden)
- Deep-water group (Ireland, Iceland, Spain, Scotland)

Prior to end of day update from group leaders and reference reviewers.

Thursday Day 2

9:30- 13:00

Continue with review groups and use of Lin's CCC on counts.

Continue with reference footage.

Prior to lunch update form group leaders and reference reviewers.

14:00 – 17:30

Continue with review groups

Continue with reference footage

Prior to end of day update form group leaders and reference reviewers.

Decide if workshop needs more review of footage or go to report writing on Friday morning.

Friday Day 3

9:30- 17:30

Footage review/Report writing.

Continue with review groups and use of Lin's CCC on counts.

Continue with reference footage.

Prior to lunch update form group leaders and reference reviewers.

14:00 – 17:30

Discuss outcomes from:

Reference reviews

Group Reviews

Training material in terms of updating SISP

Quality Control in terms of updating SISP

Burrow workshop report writing and adoption of any recommendations.

Presentations given

1. Marine Institute UWTV Training Materials and Procedures - Sean O' Connor, Marine Institute, Ireland.
2. Cefas UWTV Training Materials and Procedures - Rob Masefield, Cefas.
3. AFBI UWTV Training Materials and Procedures – Peter McCorriston, AFBI.
4. Adriatic UWTV Training Materials and Procedures – Damir Medvešek,
5. Langolf UWTV Training Materials and Procedures – Jean Phillipe Vacherot, Ifremer.
6. FU30 UWTV Training Materials and Procedures – Yolanda Vila, IEO.
7. Marine Science Scotland UWTV Training Materials and Procedures – Ade Weetman, MSS.
8. FU3-4 UWTV Training Materials and Procedures – Mats Ulmestand, SLU.
9. Introduction to *Nephrops* Burrow Identification – Ade Weetman, MSS.
10. *Nephrops* Burrows from tank experiments – Mats Ulmestrand, SLU.

Annex 3: WKNEPS terms of reference for the next meeting (draft)

The next **Workshop on *Nephrops* Burrow Counting** (WKNEPS), will meet in 2018 to:

a) Review current status of available training materials and procedures (31).

b) Train personnel in the complexities of burrow counting in different *Nephrops* grounds through group review sessions (31).

c) Produce reference counts for standardization of counter performance for remaining survey areas (27, 31).

Supporting Information

Priority	This work is considered high priority as it is crucial to keep building capacity on burrow counting skills across all institutes that are responsible to assess and advice *Nephrops* stocks where UWTV surveys are an integral part of the stock assessment. It is important to standardize this process and ensure the quality control of this method and to redefine counting protocols if needed. This workshop will be particularly important for supporting training for new and developing surveys.
Scientific justification	*Nephrops* are a valuable species whose stocks are potentially sucseptible to local depletion. UWTV surveys have become the main basis of management advice for *Nephrops* stocks in ICES. There is a need to build capacity on burrowing counting skills and support counting procedures for new and developing surveys.
Resource requirements	The venue, time and duration will be decided at WGNEPS as there is a nee to separate this workshop from WGNEPS meeting.
Participants	Expected around 20 members.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are no direct linkages with the advisory committees.
Linkages to other committees or groups	There is a very close working relationship with WGNeps. It is also very relevant to stock assessment experts groups that used the survey results i.e. WGCSE, WGNSSK, and WGBIE.
Linkages to other organizations	None

Annex 4: Recommendations

Recommendation	Adressed to
1. To hold a workshop on *Nephrops* Burrow Identification in 2018.	WGNEPS

Annex 5: The hole story, Jim Atkinson (ppt)

Burrows

The hole story

Jim Atkinson

UMBSM

Nephrops

- Large burrows are relatively straightforward to identify

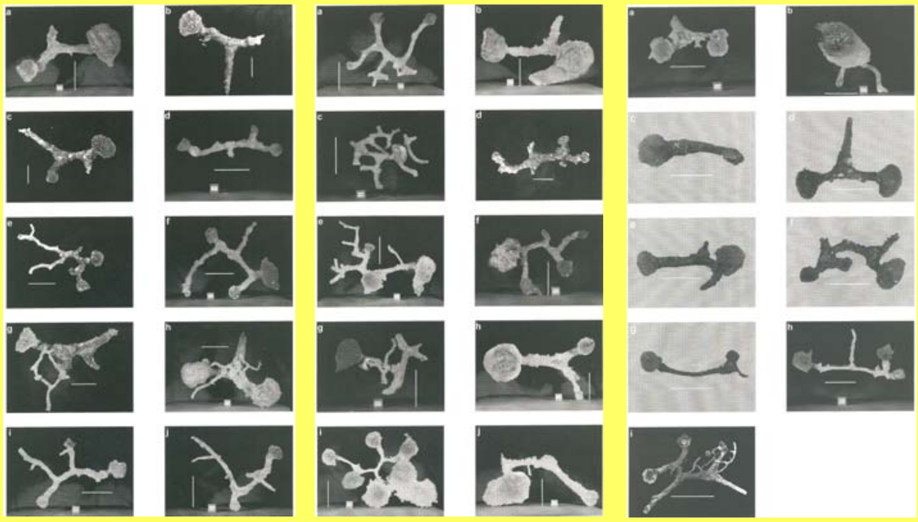
Nephrops

- *Nephrops* burrows range in complexity from single opening tunnels to complex multiple-opening systems
- NB: there is a well-established terminology for burrows: terms such as gallery, shaft, tunnel, burrow, burrow system, etc. have precise meanings for ichnologists (those who study biogenic traces and trace fossils). What *Nephrops* workers mean by 'burrow system' differs from the geological definition, but is nevertheless the best term to use in the context of the work.

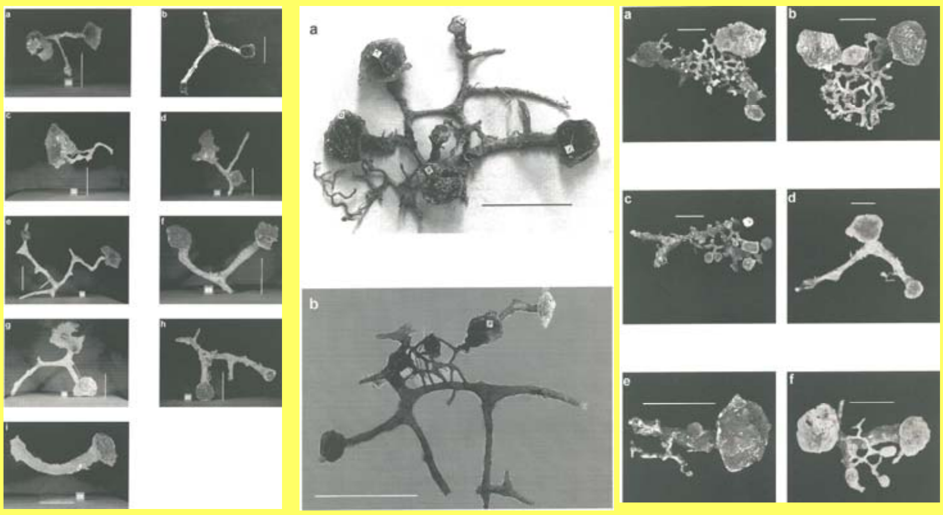
Resin Casting

Polyester resin pours underwater rather like treacle in air and when mixed with catalyst cures to produce high quality casts of burrows like this burrow of *Nephrops norvegicus* (Scale bar 20cm)

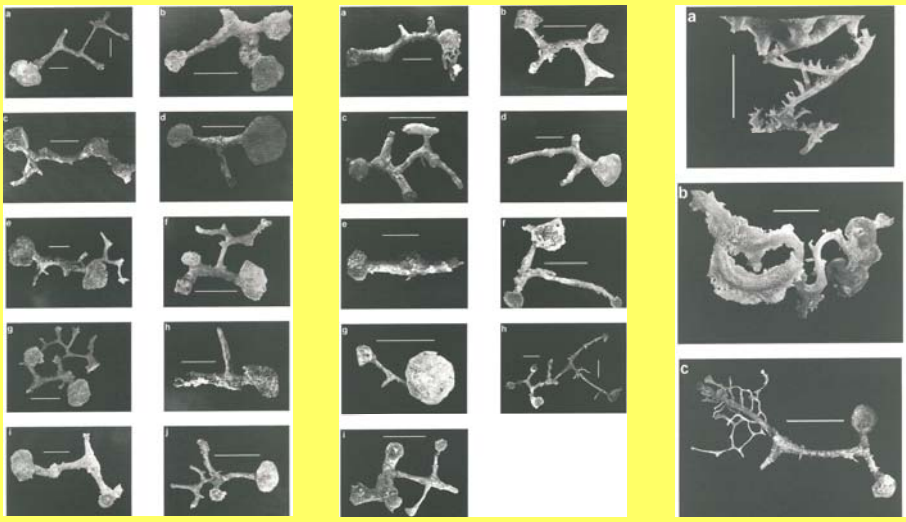
Nephrops burrows



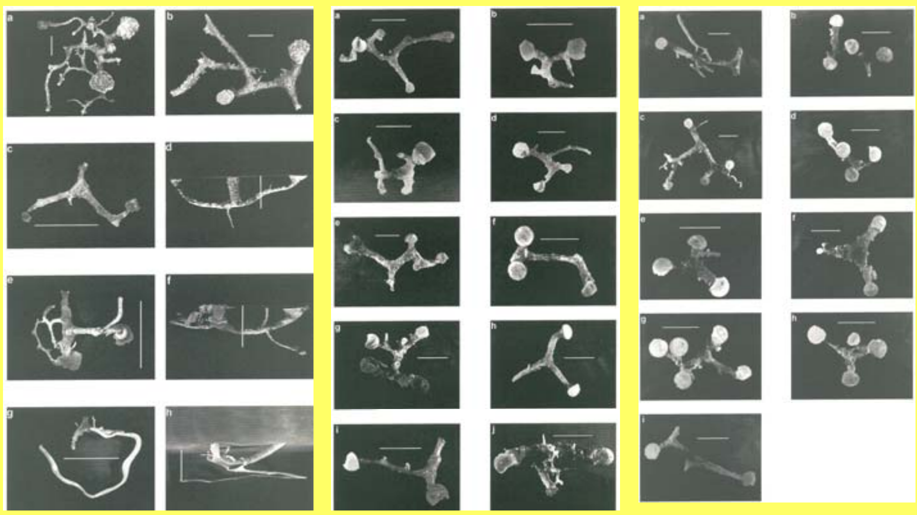
Nephrops burrows



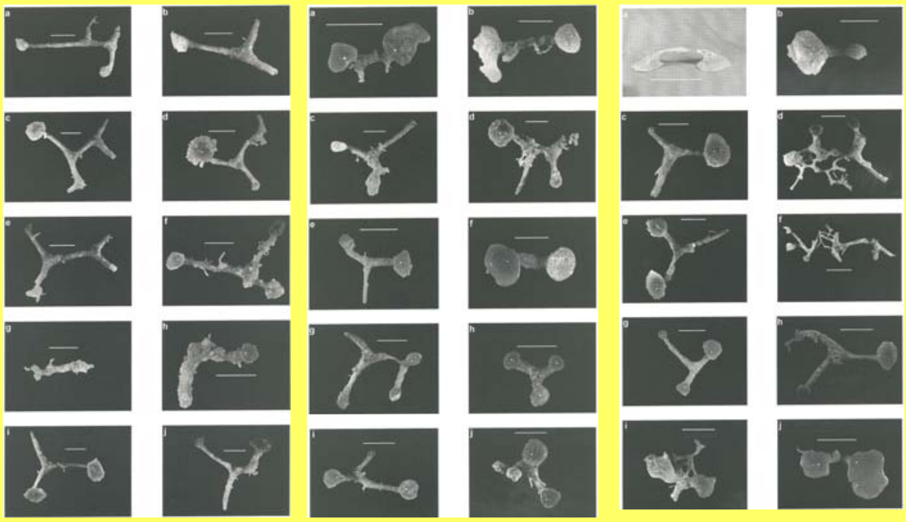
Nephrops burrows



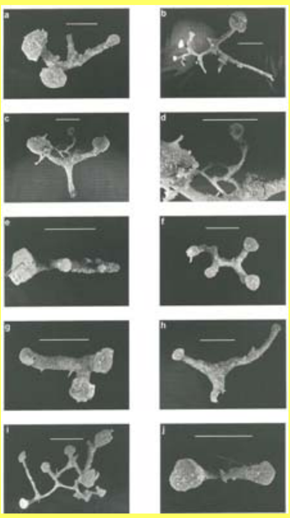
Nephrops burrows



Nephrops burrows



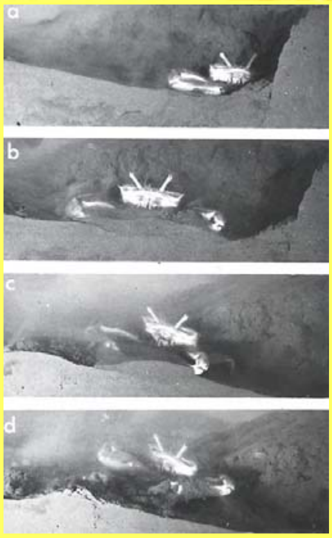
Nephrops burrows



- All of the detailed information on burrow structure comes from diver-accessed shallow water
- For those burrows cast or mapped by divers, most had two or three functional openings
- Some burrows are adult-juvenile complexes
- Some burrows are joined to the burrows of other species

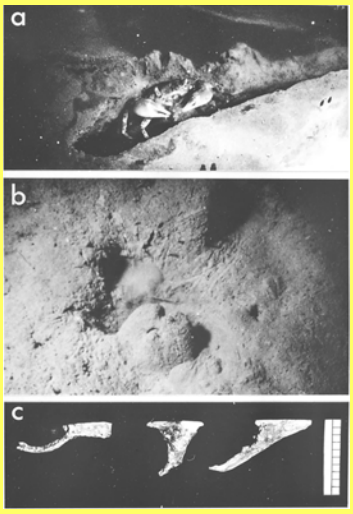
Goneplax rhomboides

- Can be confused with *Nephrops* burrows



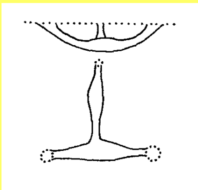
Other crabs

- Burrowers include crabs such as *Brachynotus gemmellari* (obligate - Mediterranean) and *Monodaeus couchi* (facultative – Mediterrnean & NE Atlantic)



Lesueurigobius friesii

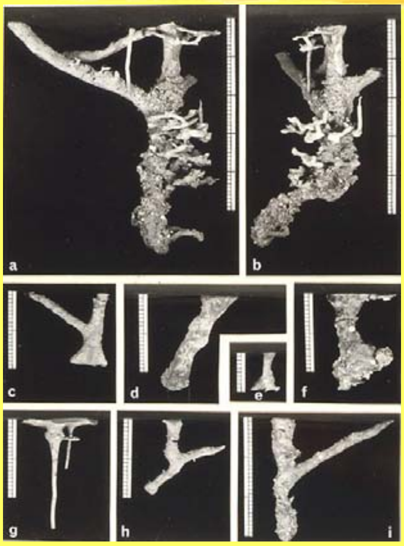
Small *Nephrops*-like burrow
Often found on *Nephrops* grounds
Openings *ca* 20 cm apart



Cepola rubescens

- Occurs on some *Nephrops* grounds
- Can cause confusion if occupant not seen
- Burrows are aggregated in distribution

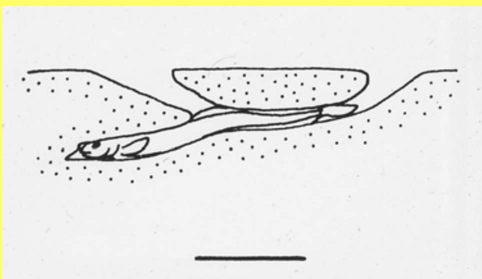
Cepola rubescens

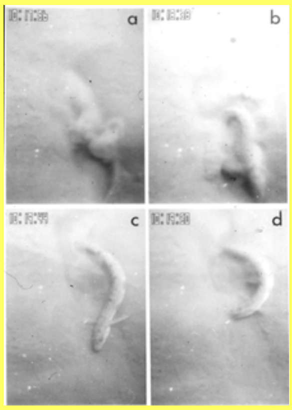


May act as a locus for other burrowing species such as *Goneplax* and callianassid shrimps

Lumpenus lampretaeformis

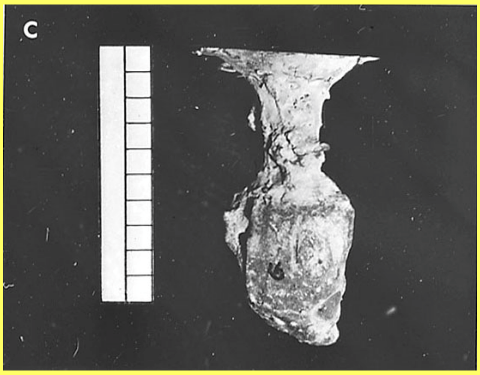
- Abundant on some *Nephrops* grounds





Gobius niger

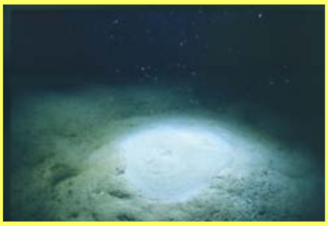
- Can construct its own burrows or secondarily occupy burrows vacated by other species
- Can co-occupy with *Nephrops*



Volcano builders

A mound builder

Maxmuelleria lankesteri



Thalassinidean burrows

- Simple burrows
  - U-shaped and Y-shaped burrows e.g. upogebiids and some callianassids
- Complex burrows
  - multi-branched and often deep burrows e.g. axiids, calocaridids, callianassids and laomediids
- Many species occur in European waters

Thalassinidean burrows

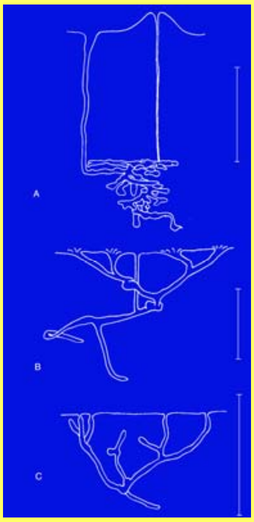
Diagrams of thalassinidean burrows

Callianassa subterranea

Jaxea nocturna

Upogebia stellata

Scale bar = 30cm



Thalassinideans

Upogebia deltaura & Callianassa subterranea

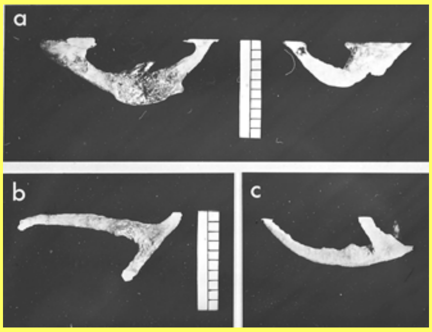
Calocaris macandreae

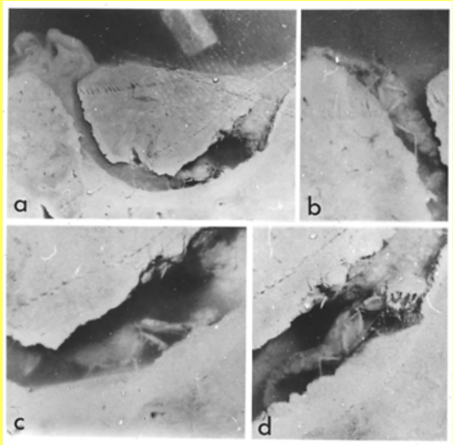
Calocaris macandreae

- Note the *Nephrops* burrows amongst those of *Calocaris*

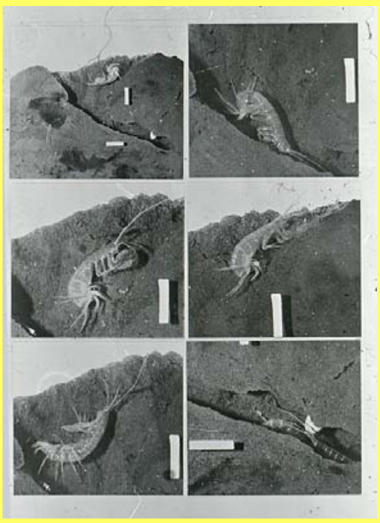
Alpheus glaber

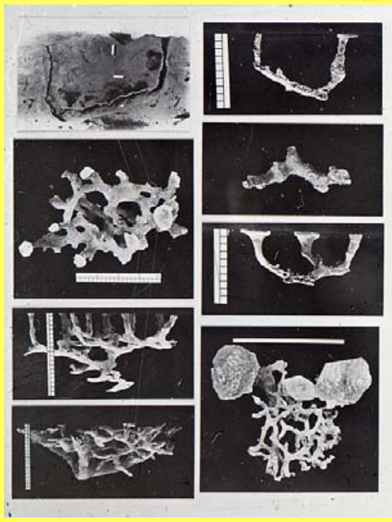
- Abundant on some *Nephrops* grounds in Mediterranean and NE Atlantic





Maera loveni - may burrow with *Nephrops*



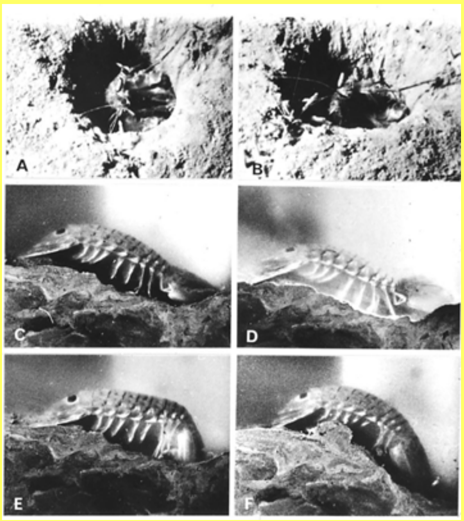


Associations

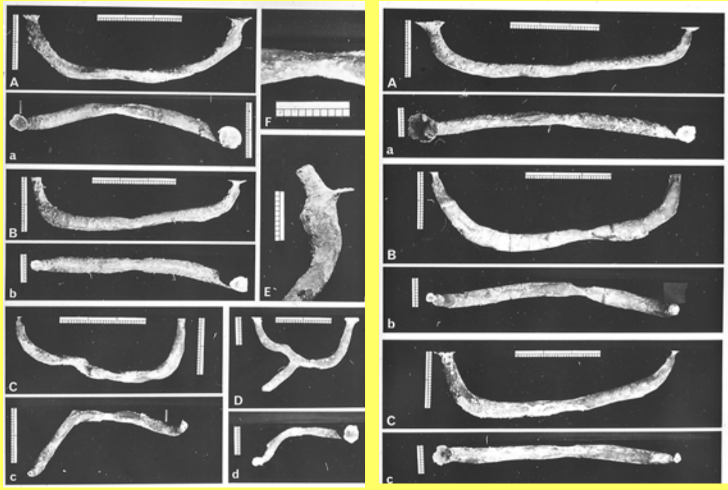
- Many burrowing species have associations with other species. A species sharing the burrow of another species is an endoekete: the association is endoecism
- This can lead to confusion about burrow identity

Squilla mantis

- Occurs on some Mediterranean *Nephrops* grounds – muddy sands



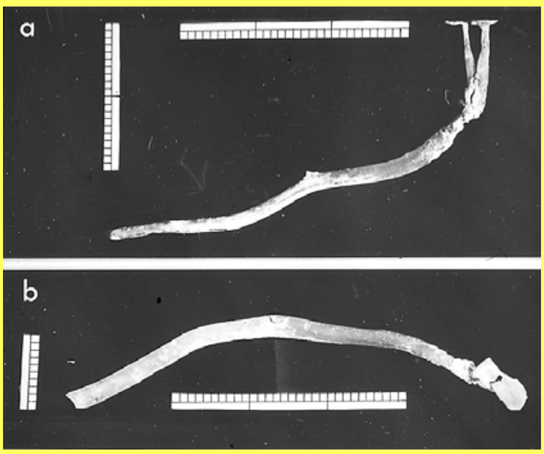
Squilla mantis



- Simple U-shaped burrow
- Circular openings, one larger than other

Bivalves

- Bivalves such as *Solecurtis* and *Thracia* species may create large burrows with distinctive, usually paired, openings



Uncertainties

- It is known that some species are burrowers, but their burrows have not been described, or descriptions are inadequate, e.g. *Enchelyopus cimbrius* (4-bearded rockling)
- Some distinctive burrow types are known but lack a known architect, e.g. various categories of 'fairy rings'
- The safest maxim when doing burrow counts for *Nephrops* assessment is "if in doubt, leave it out"