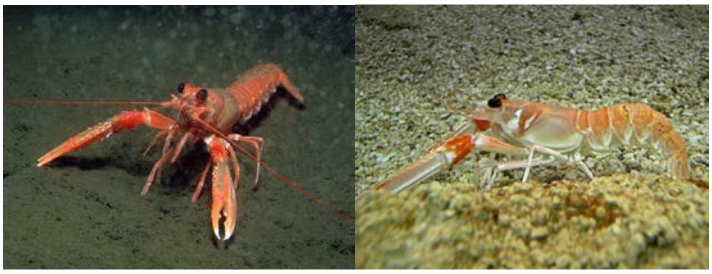
Feasibility of a Dutch *Nephrops* survey - KBWOT 2013 Get the picture

B. van Marlen, D. de Haan

Report number C203/13



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Summary

The wish was expressed in the Netherlands to set up a *Nephrops* survey. Such surveys are carried out in other ICES member countries, e.g. the UK, Ireland, Denmark. Contacts were made with experts from these countries and IMARES participated in ICES WGNEPS in 2013 to retrieve information on the procedures and instrumentation used. A standard technique is to use a UWTV-sledge with cameras to count *Nephrops* burrows and estimate abundance. A UWTV-survey is preferred over a survey using a headline unit on commercial fishing gears. It will supply a fisheries independent abundance estimate, and has developed into a standard method within ICES.

Aspects of methodology and technology are reviewed in the report. In addition three options for the survey are explored: one using a Dutch research vessel with international experts participating and using own equipment, one using a Dutch research vessel with international experts participating and using their equipment, and one using a research vessel from abroad with international experts participating and using their equipment. It appeared that the first option can be cost effective provided that vessel costs, and costs for a winch, blocks and cable will be covered by the vessel owner (Ministry of Economic Affairs). Initially the costs are relatively high, but in later years when staff has been trained and equipment developed these costs will be substantially lower.

If the *Nephrops* survey may also be used to retrieve additional data, and can possibly be extended to other purposes. A UWTV sledge can in principle also be used to support other tasks, e.g. viewing the sea bed or taking samples from the sea bed in other surveys. Option 1 also avoids the risk of having to invest in replacement or repair of equipment owned by others in case of loss or damage.

The final choice will depend on available funding for a *Nephrops* survey.

1. Introduction

In recent years the Dutch fisheries on *Nephrops norvegicus* L. or prawns has grown from about 600 tonnes to 1500-200 tonnes per year (Steenbergen en van der Hammen, 2011, see Figure 1). For the purposes of stock assessment, *Nephrops* are split into a number of stocks or 'functional units' (FUs; Figure 2) based on the discrete patches of mud which they inhabit. The two most important areas for Dutch *Nephrops* fisheries are **Off Horn's Reef (FU33)** and **Botney Gut-Silver Pit (FU5)**, and in 2011 the Dutch took the largest share from these areas (ICES, 2012):

- Botney Gut (FU5): 480 tons, followed by Great Britain with 350 tons of a total of 1053 tonnes.
- Off Horn Reef (FU33): 403 tonnes, followed by Denmark with 396 tonnes of a total of 1191 tons.

Information on the status of the stock is important for management. Unlike fish, *Nephrops* cannot be aged directly and therefore the assessments make use of size composition data from catches, combined with information on stock abundance obtained from underwater television (UWTV) surveys. During these UWTV surveys an underwater video camera is towed over the sea bed using a towed sledge. By counting the number of burrows of *Nephrops* in the seabed and relate this to the area covered by the survey a density estimate of *Nephrops* can be made. This method is already widely used on Scottish (Marine Science Scotland, Aberdeen) and Irish (Marine Institute, Galway) fishing grounds. The information gathered provides an index of stock abundance for each FU which is independent of the fishery and burrow emergence patterns. By applying a number of 'correction' factors to the index, an estimate of the absolute abundance of *Nephrops* is obtained.

Trawl surveys are believed not to reveal the status of the stock very precisely, because *Nephrops* live in burrows in the sea bed (Howard, 1989) and may often not be susceptible to capture, particularly the females.

The stocks of Nephrops in ICES Area III and IV cannot be considered as one stock. The WKLIFE considered the following *Nephrops* stocks: FU 5 (Botney Gut - Silver Pit), 10 (Noup), 32 (Norwegian Deep), and 33 (Off Horns Reef). All four stocks were considered to belong to category 6 (data-limited stocks) including stocks for which only landings data are available. Concerning the Botney Gut – Silver Pit (FU5) area it was found that over the last 15 years the national composition of the fleet fishing this FU has changed with Belgium reducing its landings and the UK increasing. In 2010 and 2011, the UK and Netherlands continued to dominate the fishery taking ~80% of the landings from this area. Germany continued to take around 14% in both years whilst Denmark's and Belgium share remained small. The size of the UK fleet prosecuting this fishery has declined sharply from seven vessels in 2009 to three in 2010 and just one in 2011. *Nephrops* in FU5 are caught by trawling. There is no creeling in the area. In the most recent years UK and Netherlands have accounted for most of the landings from this FU. Both mean sizes of males and females show an increasing trend over time. The status of this stock is uncertain although there are no consistent signals that this stock is suffering from over-exploitation. The 2012 survey shows that density is relatively high on this ground at 0.7 burrows per metre squared. 10 year average landings of 1000 at this density equates to a harvest rate of around 3.8%. As management advice the report mentioned: The North Sea TAC is not thought to be restrictive for the fleets exploiting this stock, considering the recent trend in LPUE and technological creep of the gear, the exploitation of this stock should monitored closely (ICES, 2013).

For Off Horn's Reef the following was concluded: The landings from FU 33 were marginal for many years. However, from 1993 to 2004, Danish landings increased considerably, from 159 to 1,097 t. In this period Denmark dominated this fishery. The other countries reporting landings from the area are Belgium, Netherlands, Germany and the UK. In 2007 total landings increased to above 1400 t. Since 2004 Danish landings have gradually decreased, and was almost 400t in 2011. During the same period landings from Netherlands increased. In 2011 total landings from this FU amounted to almost 1200 t (Table 3.3.8.1), of which the Netherlands accounted for around 400 t. The other countries contributed with around 400 t. The 10-fold increase in fishing effort from 1996 to 2004 seems to correspond to the increase in landings during the same period. Dutch effort data are available from 2005-2011 and was around 1500 days in recent 6 years. LPUEs from Netherland increased from 200 kg/day in 2006 to around 300 kg/day in 2007-2009 and fall to around 200 kg/day in 2010 and 2011. The management consideration was that the North Sea TAC is not thought to be restrictive for the fleets exploiting this stock, and considering the recent trend in LPUE and the technological creep of the gear, the exploitation of this stock should monitored closely (ICES, 2013).

For an overview of surveys carried out per FU see Table 2. Recently CEFAS (Lowestoft, UK) has started carrying out a survey in the Botney Gut as well. Off Horn's Reef is until now not being monitored.

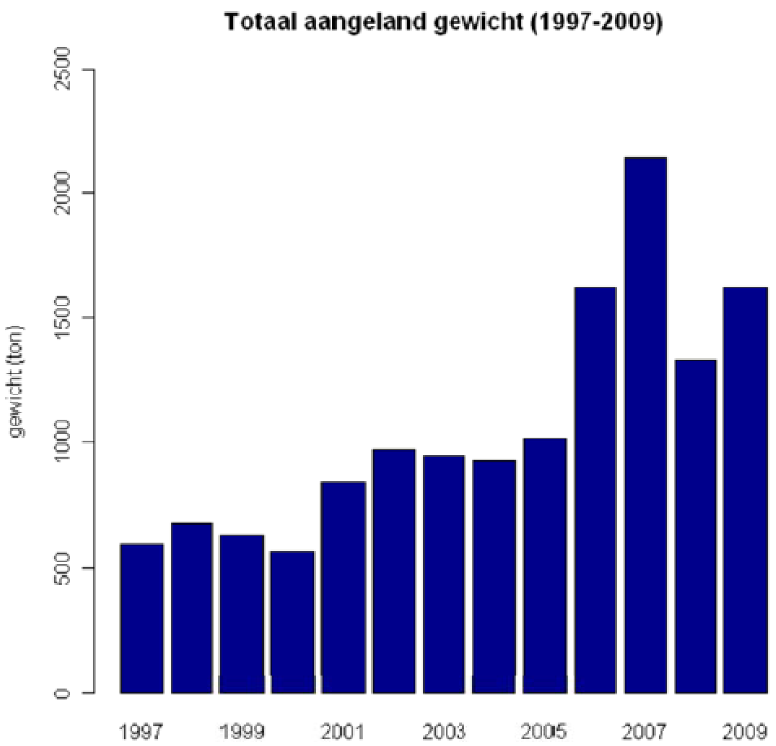

Figure 1. Nephrops landings (tonnes) in Dutch harbours (Hoeveelheid Noorse kreeft (ton) aangeland in Nederlandse havens (Steenbergen en van der Hammen, 2011)).

1.1 Need expressed

Although CEFAS has started carrying out a TV-survey in Botney Gut in 2010, the continuation of this survey is rather uncertain. During a tri-lateral informal meeting with IMARES, CEFAS and ILVO in May 2012, Ana Leocardio (responsible for the implementation of all TV-Surveys in CEFAS) expressed the wish to cooperate as CEFAS is facing financial problems and most likely in the future there will be no money for the Botney Gut Survey. As no monitoring is carried out in Off Horn's Reef and the future of the monitoring in Botney gut is uncertain no sufficient information is available for the most important Dutch fishing grounds. This could in the future have consequences for the quota.

If a country is one of the largest users of a stock, this country should have a responsibility for the monitoring of that stock. Logically, therefore, the Netherlands should take a role in monitoring of *Nephrops* in the North Sea. Also in international fora, in which surveys are coordinated by Member States, it was discussed that in the future surveys for stocks should be organised and financed together by those countries with the greatest interest (pers. comm. Frans van Beek: RCM DCMAP).

Also the Dutch fishing industry finds it important that the Netherlands gets involved in the monitoring of Nephrops. Pim Visser (VisNed) wrote in an e-mail on 2 August 2012: "... Gezien het toenemende NL kreeftjes belang lijkt het me belangrijk om hieraan bij onderzoekssamenwerking aandacht te schenken. Onze NL betrokkenheid is belangrijk. Zo ook bij Off Horn's Reef (vlgs mij 'De Paal') waar nog geen onderzoek gaande is.... op die manier, vraag ik jullie om dit onderwerp met prioriteit op jullie onderwerpenlijst te zetten. "

As a response Henk Offringa (Ministry EZ) stated that funding this research is negotiable if the DCF reveals that Netherlands has a responsibility here (research cooperation, September 3, 2012, Rijswijk).

2. Project details

2.1 Objective of the project

To investigate the possibility to carry out a underwater television (UWTV) survey and establish international cooperation for *Nephrops* in Off Horn Reef and a possible continuation of the UWTV-survey in the Botney gut.

2.2 Work plan

This project focussed on the possibilities of conducting a TV-Survey for *Nephrops* in two important fishing areas. By the end of the project it was aimed to have a complete picture of the practical implementation of a TV-Survey for monitoring *Nephrops* including an overview of possible improvements.

The following work was done

1. Literature search.
2. Contact with *Nephrops* survey experts.
3. Participation in ICES WGNEPS met on 5-8 November 2013 at the ICM-CSIC (www.cmima.csic.es) in Barcelona, Spain.
4. Calculation of the costs of various scenarios for the survey.

2.3 Project outcome

Cost estimates for various options and an action plan for the monitoring of *Nephrops* stocks in Botney Gut and Off Horn reef in 2014 and following years. As financing is the crucial element in deciding to organise such a survey the focus lies on these cost estimates.

3. Background information

3.1 Nephrops biology

Nephrops distribution is limited by the extent of suitable muddy sediment in which animals construct burrows (Anonymous, 2013). There are populations in the North Sea and waters to the west of Scotland, in open waters and sea lochs at depths ranging from a few meters down to over 500 m on the shelf edge, west of the Hebrides.

Nephrops spend most of their time in burrows, only coming out to feed and look for a mate. They are opportunistic predators, primarily feeding on crustaceans, molluscs and polychaete worms. Female *Nephrops* usually mature at three years of age and reproduce each year thereafter. After mating in early summer, they spawn in September, and carry eggs under their tails (described as being 'berried') until they hatch in April or May. The larvae develop in the plankton before settling to the seabed six to eight weeks later. Reproductive timing may be slightly delayed in the deeper areas of the Fladen Ground.

Nephrops in different areas grow at different rates and mature at different sizes. This variation is related to the density of animals and sediment type. On the softest mud, *Nephrops* density is low, but the animals grow relatively fast, and reach a larger maximum size ('clonkers'). On sandier mud, *Nephrops* density is much higher, but the animals grow relatively slowly, and are smaller ('beetles'). In the North Sea there are differences in growth between stocks, while on the west coast, there are also differences between areas within the same stock.

Since most *Nephrops* fishing is by trawling, and animals are protected from trawls when in burrows, the emergence patterns affect catch rates. The timing of emergence to feed appears related to light level, and greatest catches are often taken at dawn and dusk, although this may vary with water depth and clarity. As 'berried' females rarely come out of the burrow, they are naturally protected from trawlers, and males dominate trawl catches for most of the year, and are more heavily exploited than females. This is the reason why trawl surveys may not cover the entire population, and therefore the method of counting burrows by UWTV-surveys and inferring *Nephrops* abundance by assuming an occupancy rate is taken up as a preferred procedure.

Source: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/nephrops.

3.2 ICES reports

An overview of fishing grounds and Functional Units (FUs) and a review of existing UWTV-surveys for *Nephrops* are given in (ICES, 2007). In the North Sea annual UWTV surveys now cover stocks that account for approximately 77% the total landings from the IIa and IV TAC areas. In the west of Scotland the annual surveys now cover stocks that account for 97% of the VI TAC and experimental surveys are carried out in deeper waters along the shelf, at Rockall and on the Stanton Banks.

Nephrops are limited to a muddy habitat. This means that the distribution of suitable sediment defines the species distribution and the stocks are therefore assessed as nine separate functional units (FUs). A detailed map of FUs in the North Sea and Skagerrak/Kattegat region is given in Figure 2, and information on ICES squares in Table 1. The two FUs of interest for this project are: FU5: Botney Gut – Silver Pit, containing 10 ICES rectangles, and FU33: Off Horn's Reef with 6 rectangles.

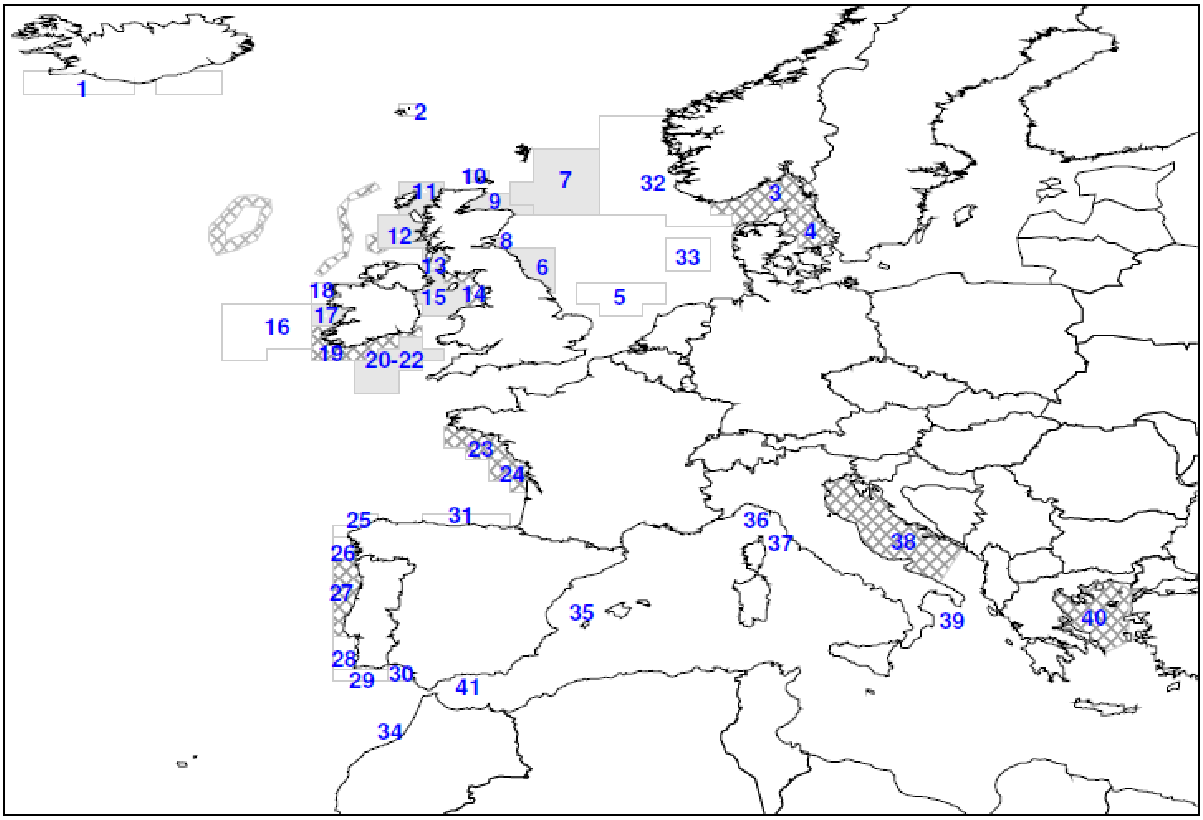

Figure 2. Nephrops stocks and fishing grounds in European waters. Stocks and grounds with annual Nephrops UWTV surveys is shown in filled grey and areas with experimental or planned surveys are indicated with hatched grey. From: (ICES, 2007). Numbers represent Functional Units (FUs), Off Horn Reef = FU33, and Botney Gut-Silver Pit = FU5.

Table 1. Nephrops functional units in the North Sea and Skagerrak/Kattegat region with ICES division and statistical rectangles.

FU no.	Name	ICES division	Statistical rectangles
5	Botney Gut – Silver Pit	IVb,c	36–37 F1–F4; 35 F2–F3
6	Farn Deeps	IVb	38–40 E8–E9; 37 E9
7	Fladen Ground	IVa	44–49 E9–F1; 45–46 E8
8	Firth of Forth	IVb	40–41 E7; 41 E6
9	Moray Firth	IVa	44–45 E6–E7; 44 E8
10	Noup	IVa	47 E6
32	Norwegian Deep	IVa	44–52 F2–F6; 43 F5–F7
33	Off Horn's Reef	IVb	39–41 F5–F6
34	Devil's Hole	IVb	41–43 F0–F1

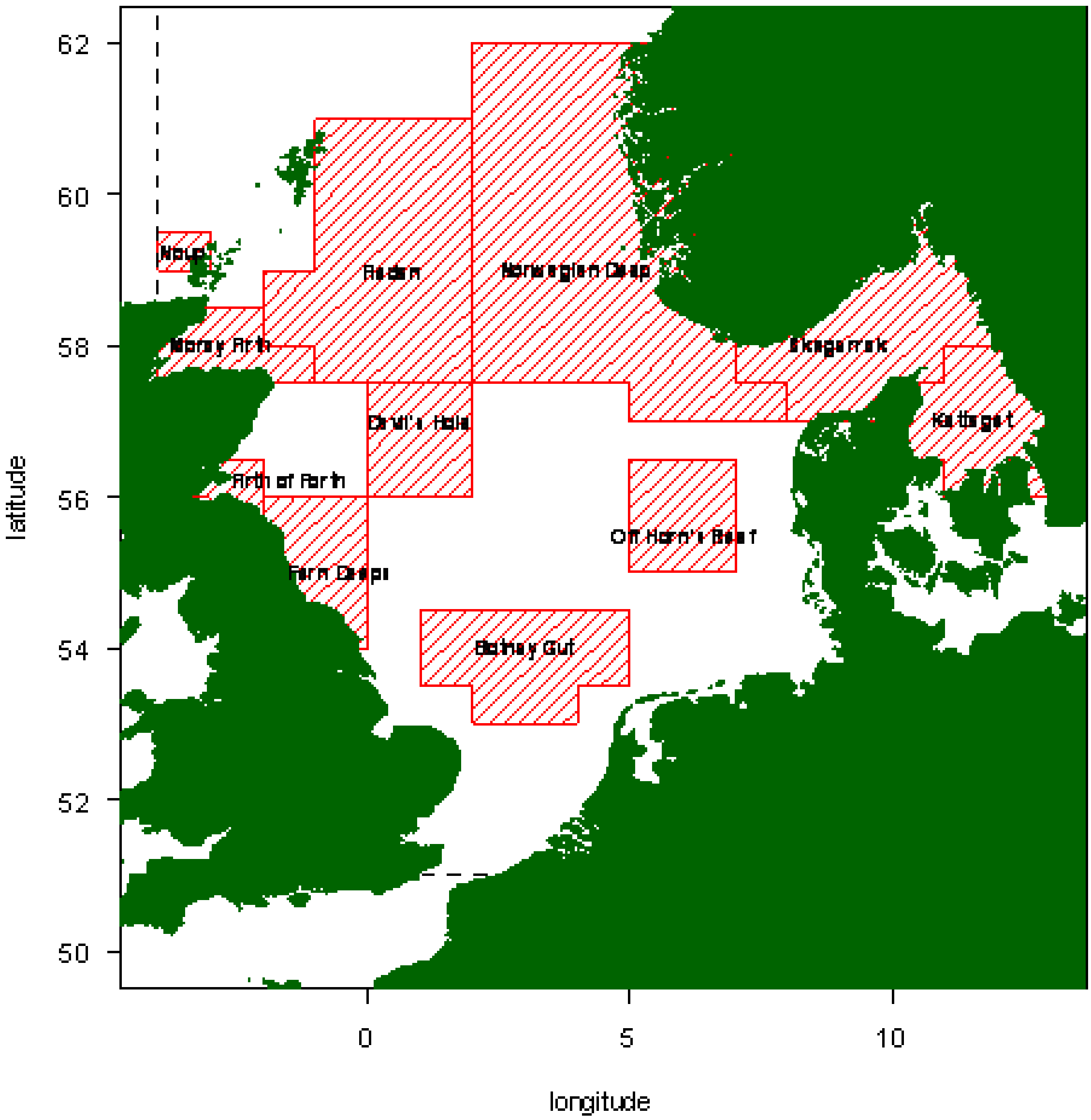

Figure 3. Nephrops functional units in the North Sea and Skagerrak/Kattegat region.

3.3 Dutch *Nephrops* landings and fishing grounds

When conducting a survey it is important that the surveyed area matches areas of substantial fishing effort and resulting landings. We used a plot of the landings of *Nephrops* with the coordinates (ICES rectangles) of both areas (Figure 4 and Figure 5). Both areas cover the high density spots.

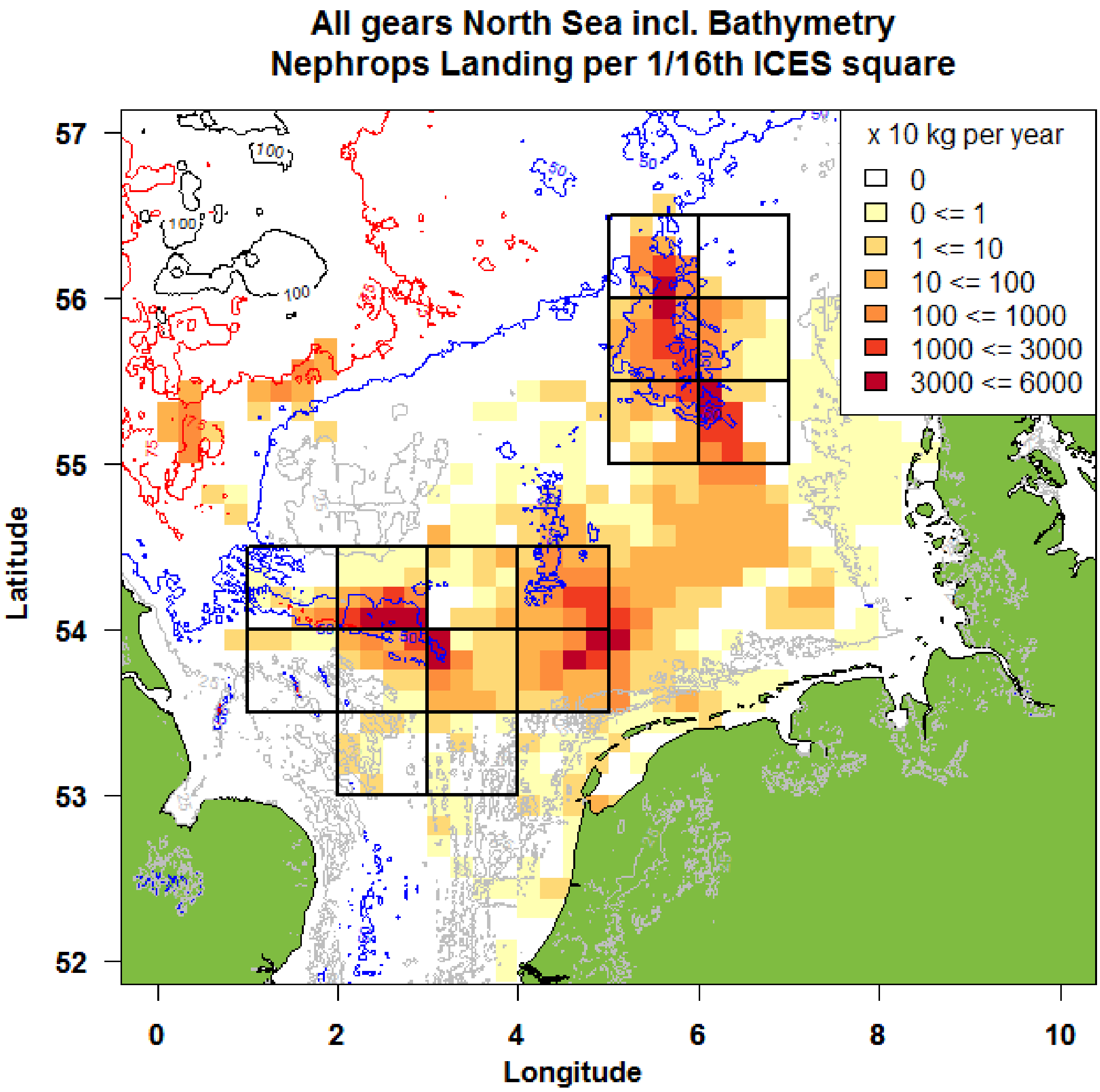

Figure 4. All Dutch Nephrops landings in 2011 (1 Mkg in total; from all gears) in the North Sea per 1/16 ICES-square. Left is Botney Gut – Silver Pit, middle right is Off Horn's Reef.

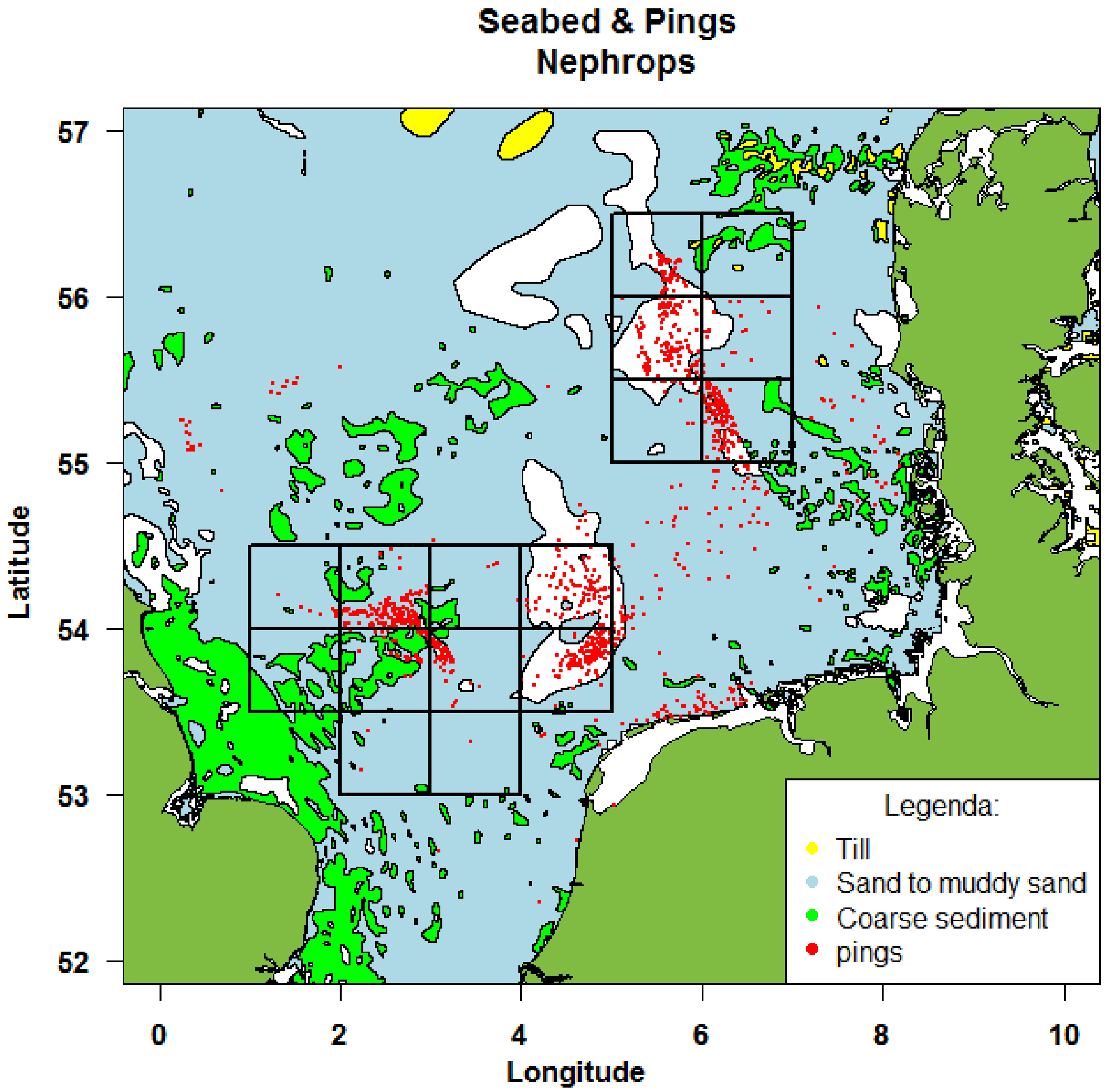

Figure 5. Sea bed characteristics and pings fished positions of all Dutch vessels in 2011 in the North Sea in relation to the two survey areas indicating the most intensively fished areas. The black squares are ICES rectangles. Left is Botney Gut – Silver Pit, middle is Doggerbank and right up is Off Horn's Reef. The VMS detections are based on a scale 1:10 (every ping is 10 detections).

4. Survey design and requirements

4.1 Requirements for using UWTV technology

4.1.1 Equipment requirements

The UWTV equipment consists of a towed sledge running over the sea bed. On this sledge there are cameras to observe *Nephrops* burrows, equipment to take sediment samples, navigation instrumentation, lights to illuminate to bottom track, and video equipment. Various designs of sledges are currently used (ICES, 2007), see Figure 9 and Figure 10. The equipment applied on the survey sledge is more or less similar for each country. The Irish, CEFAS and MSS devices are almost equal in dimensions. There are some different sensor applications. The Irish line out is the most versatile (Figure 6) and contains an expensive transponder/receiver set with which the actual position changes of the sledge relative to the ship's heading is monitored. This option requires an expensive acoustic receiver dome on the ship's hull.

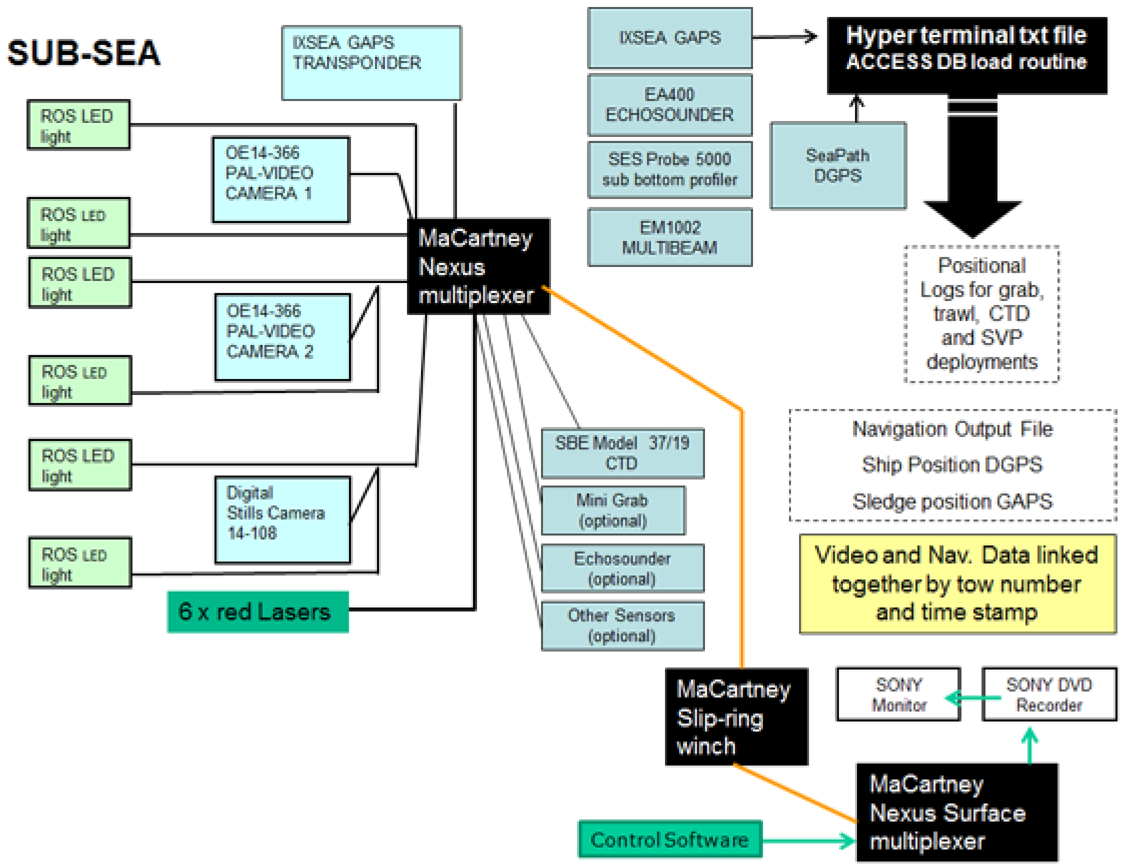

Figure 6. Schematic overview of instruments involved in the Irish towed sledge system (presentation Colm Lordan, WGNEPS meeting, Barcelona 2013).

The Irish design also includes a Seabird CTD device (Type SBE 37/19) with which a contour plot of the bottom temperature is made for the complete survey area (Figure 7). In between stations a multi-beam echo-sounder is used to map the bottom profile. This is additional information about the habitat of this species. The equipment has a twin set of video cameras rigged at different angles to reduce the shading effects of the contours of the burrow entries, but in most cases the second device acts as an on-line available second source in case of failures. Both the MSS and CEFAS equipment do not contain a transponder/receiver set for the sub-sea position of the sledge. The CEFAS equipment includes a CTD device with a turbidity channel. All sledge configurations have a laser ruler to determine the observed width of the stratum. The Irish sledge contains a set of six modules, three per side. All systems are rigged with LED light modules under different angles for illuminating the observed area. All systems have an odometer (wheel) to measure the observed length. The MSS sledge has a camera pointed at the wheel to observe irregular functioning and a battery powered video camera at the rear side of the sledge facing backward. The Danish/Swedish scientists reported not to have a very good experience with the odometer performance and instead the video frame rate will be used to calculate the distance of the track.

A useful instrument for acquiring the type of stratum is a multi-beam acoustic system included on the Irish sledge and under development for the CEFAS sledge. The seabed characteristics of *Nephrops* habitat is mainly mud, muddy sand, and can be related to VMS data, which decline sharp when the bathymetry changes. Survey stations will also have to be positioned on the edges of these slopes. Additional data on the sediment during the survey and the relation to burrow counts is useful and recommended to increase precision. The costs for such all tool however, are very high and a future wish for investments. Another cheaper way to monitor the sediment type is to apply a software tool connected to the hardware of an echo-sounder attached to the sledge or vessel, like the QTC (Quester Tangent) tool tested in 1998 to discriminate mussel grounds in the sediment (de Haan C031/98, 1998).

Safety precautions against the loss of the sledge due to obstacles or cable failures are highly recommended. The easiest way is to use floatation and a rope attached to the rear part of the sledge as done by some of the institutes. This can also be done by triggering an electro-magnetic valve, which releases a warp and floatation.

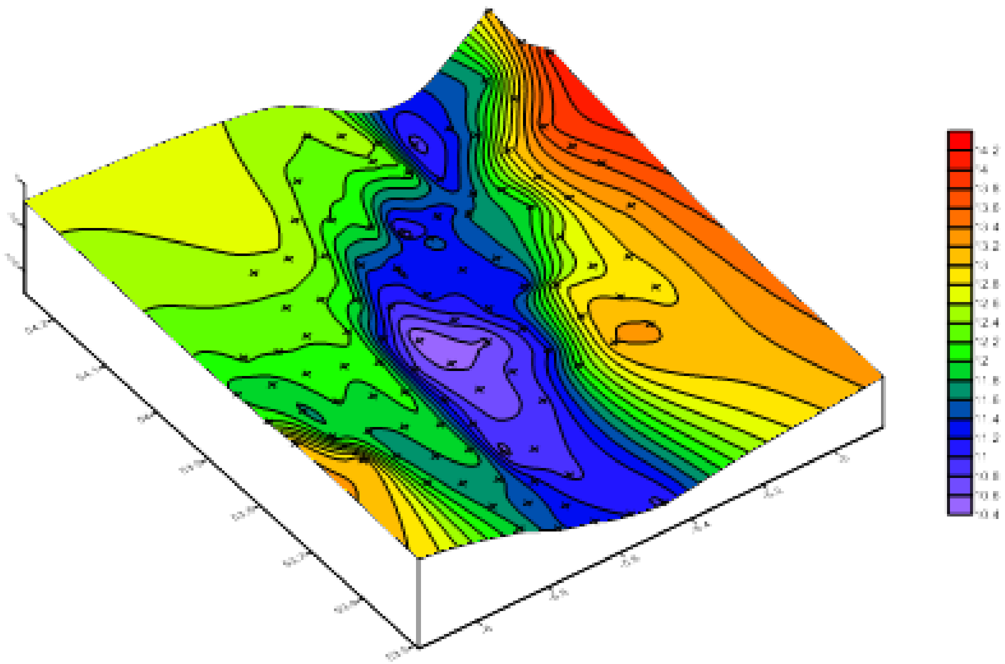

Figure 7. Bottom temperature contour plot based on Seabird CTD data of the Irish Sea (presentation Colm Lordan, WGNEPS meeting, Barcelona 2013).

4.1.2 Vessel requirements

The working schedule on-board the vessel should enable a 24 hour observation cycle 7 days a week. The ideal survey towing speed applied is 0.7 knots on average. The possibility of maintaining the vessel's track depends on the wind catching square area of the vessel and the wind force. Some European research vessels are equipped with a dynamic positioning (DP) system to maintain track on these low speed conditions. The winch is controlled at the wheel house for shooting and recovery of the sledge and is taken over by the research operator to land the sledge on the seabed and to stabilise the sledge operation by adapting the umbilical length. The umbilical length is acquired by a rotational counter in the umbilical guiding block, which can be calibrated to a count/m length. The shooting and recovery is ideally arranged over de stern by using a frame such as on board RV "Celtic Explorer" (Figure 8) exploited by MI, Galway, Ireland. The Dutch research vessel RV "Tridens" is equipped with a controllable heck frame, which was also used to launch the Dutch RV's in the past. This method can be copied or else the towing over the port board side would be a safe option to consider. The video observation desk should be suited to install a twin set of video monitors with for two observers to execute real-time counting. The post analysis is carried out in another room separated from real-time observations. Data of the ship's DGPS system will be required to be linked to the observed track including the data of the towing speed at the level of the observes and as a channel in the logs ship's data. In addition the vessel should be able to operate a small (2m wide) beam trawl to estimate the *Nephrops* length distribution per station.

Figure 8.Recovery of the MI, Galway sledge on board RV "Celtic Explorer" (presentation Colm Lordan, WGNEPS meeting Barcelona 2013).

Given the relative large distances that have to be covered and the remoteness of the two survey areas a vessel is needed that can sail at fairly high speeds and forms a stable working platform. In addition the vessel should be able to sail at very low speed with precision.

4.1.3 Survey requirements

Executing a fishery independent Dutch *Nephrops* survey by use of an underwater observation technique is in line with the choice of other European countries. As this species is stationary on a location and does not migrate a survey fishing gear can be deployed on a few stations per area to estimate the length distribution.

The execution of a *Nephrops* UWTV survey requires a 24 hour a day operation which is a labour intensive operation. A minimum staff consists of 4 video observers, a junior scientist and a technician. The survey procedure is based on a observed track of 10 minutes, during burrows are counted manually by a crew of two observers per 6 hours shift. In the remaining time of the shift the post-analysis is executed per shift. In this procedure all the analysis is done on-board the vessel. The benefit of this number of available staff is that all the analysis can be carried out at sea and no additional laboratory work has to be done. In the first two years IMARES staff will have to be trained by experts of another European Institute and these experts (usually one scientist and one technician) will have to join the surveys.

Participants in WGNEPS are currently writing an ICES Cooperative Research Report (CRR) describing the biology, observation and analysis technique in detail. This will be the most detailed document so far for participants to start a *Nephrops* survey with all reference material available, and is expected to be published in 2014. This document will be needed to update the survey requirements.

4.1.4 Development automated video image analyser tool

A new automated analysis technique with image analysis software in order to discriminate or identify burrow mosaics is under development by MI, Galway in cooperation with the Trinity College of Dublin (PhD). This technique comprises video enhancement to optimise the footage and to reduce vignetting, which is a reduction of an image's brightness or saturation at the periphery compared to the image centre (source: Wikipedia) and optimise the contrast. The first laboratory trials on existing video footage showed a very low error rating and it promises to be a new tool in excluding human errors in the counting of burrows. It is unclear to what extent this tool will affect the labour costs for data processing during the analysis.

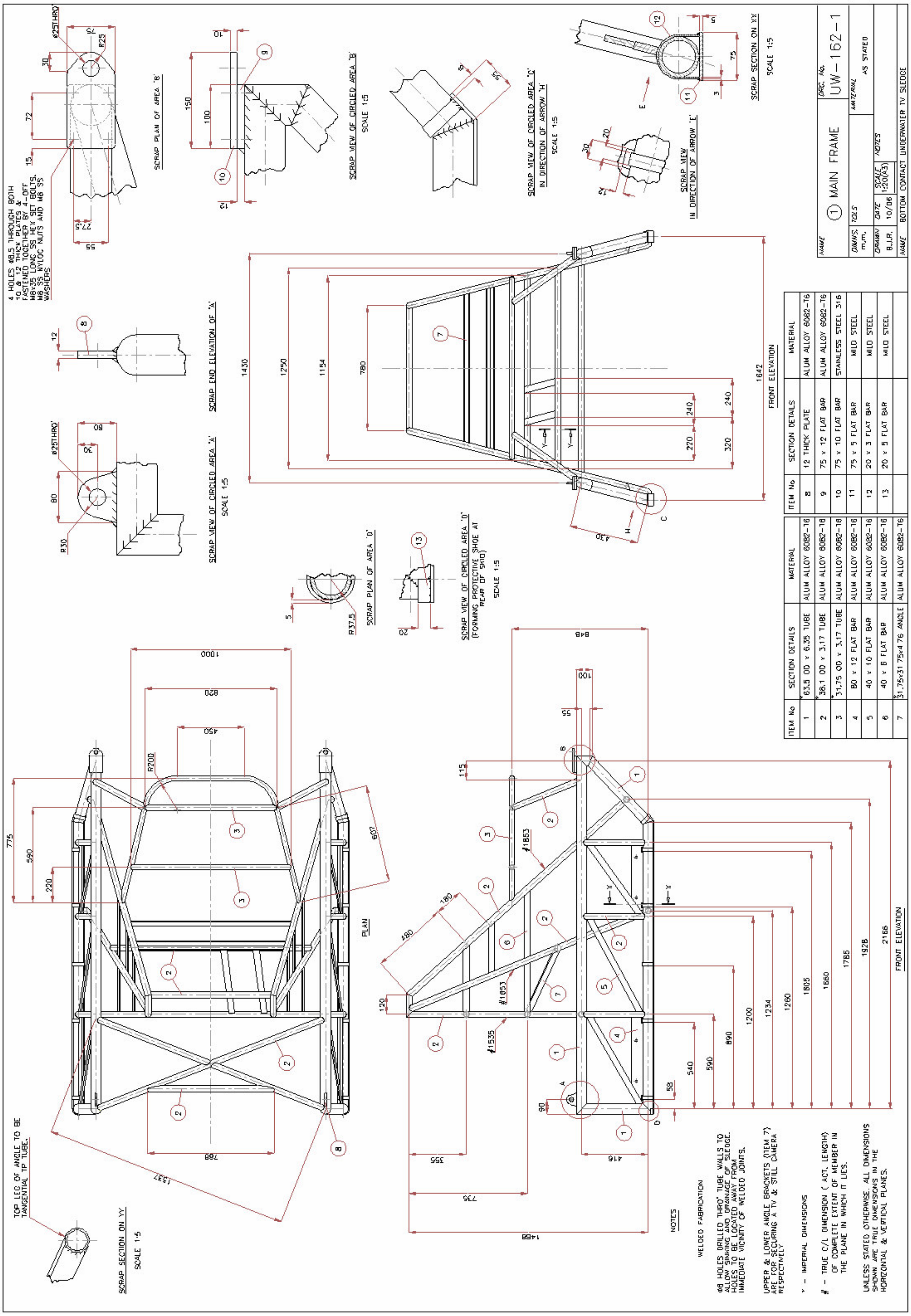

Figure 9. Technical construction drawing of the MSS UWTV sledge.

Figure 10. UWTV sledges used, left MSS, right CEFAS.

4.2 Survey design

Survey design developed over time, and is not identical for each FU (Table 4). In some FUs (7, 8, 9, 10, 11, 12, 13) a random stratified design is used, in other a grid design (5, 6, 14, 15, 17, 19, 22), or a grid with random selection i.e. in FU 3 and 4.

Traditional random or random stratified designs may result in poor geographical coverage of the ground in some years, owing to the random nature of station locations. To address this concern, a number of surveys have adopted either a random fixed grid design, or a random design stratified by a grid or combination of grid and sediment strata. The advantage of the fixed grids design, depending on the resolution, is that it reduces the concerns about poor coverage, and potentially provides a more appropriate survey dataset of geo-statistical analysis approaches. The main disadvantage is that with fixed grids there needs to be adequate coverage.

In so-called adaptive survey designs sample variances are computed from an initial part of a stratified survey and these estimates used to adaptively allocate the remaining samples among the strata (ICES, 2000).

Table 2. Survey characteristics in participating states.

Institute	Survey design	FU	FUs covered	Area (km^2)	mean # stations (2005-2011)	# stations / 1000 km2	Quarter	Vessel
MSS, UK Scotland	random stratified	7	Fladen	28153	71	2.5	Q	Scotia
	random stratified	8	Firth of Forth	915	46	50.3	Q3	Clupea
	random stratified	9	Moray Firth	2195	45	20.5	Q3	Clupea
	random stratified	10	Noup	400	6	15.0	Occasional	?
	random stratified	11	North Minch	1775	37	20.8	Q2	Scotia
	random stratified	12	South Minch	5072	34	6.7	Q2	Scotia
	random stratified	13	Clyde	2083	40	19.2	Q2	Scotia
CEFAS, UK England	grid	5	Botney Gut & Silver Pit	1000	43	43.0	Q	Endeavour
	grid	6	Farn Deeps	2750	108	39.3	Q3	Endeavour?
	grid	14	Eastern Irish Sea	1043	36	34.5	Q	Endeavour
?	grid	22	Smalls	2800	91	32.5	Q	Endeavour
Marine Institute, IE	grid	15	Irish Sea West	5331	145	27.2	Q3	Celtic Voyager
	grid	17	Aran Grounds	926	74	79.9	Q	Celtic Voyager
	grid	19	SW & South of Ireland	1572	35	22.3	Q	Celtic Voyager
DTU Aqua, DK	grid with random selection	3..4	Kattegat & Skagerrak	9842	72	7.3	Q	Havfisken?

4.2.1 *Number of stations needed determined by simulation*

A simulation was carried out using the 2006 CEFAS Farn Deeps survey data. This survey was chosen as it samples 90 stations within a single sediment stratum. Random selections of between 11 and 90 burrow density values, without replacement, were made, and mean burrow density calculated from these selections. This process was repeated 10000 times for each number of burrows selected. This bootstrapping process was repeated, this time testing whether the random selection of burrow densities was normally distributed, using a Shapiro-Francia test. A significant proportion of random samples produce normally distributed density values once a sample size of 46 is reached. This suggested an accurate estimate of abundance could be made using approximately <u>half the sampling effort</u>.

4.3 Survey methodology

Standard Operating Procedures (SOPs) exist from England and Wales, Scotland, Ireland, Northern Ireland and Greece, but apparently they differ in these countries to some extent. Aspects for which they differ are given below.

4.3.1 *Counting procedures*

Some institutes complete all burrow counting while still at sea (Ireland and Scotland), other do this at the laboratory (England) with a tendency to shift this work at sea, which is cheaper and saves time if readers are already on-board. Draw-back are that the ship motions may affect the accuracy of counters, and concentration can suffer from fatigue during long working days at sea. In addition counting at the laboratory may be able to draw on a wider base of trained staff. When several people work together this may help in decreasing individual counting rate and harmonizing the variance of results. But trials showed that counting is best performed in isolation.

The majority of laboratories count burrow complexes, the number of *Nephrops* observed in burrows and the number of *Nephrops* observed on the surface. Some laboratories use a line a few centimetres up from the bottom of the screen to count passing borrow openings, others use the bottom of the screen.

Some laboratories split the 10 minute interval in 1 minute blocks, others use the full 10 minutes. Split intervals increase the data for statistical analysis, and cause less fatigue. Slowing the video down while playing may cause a loss of resolution of the image. Live counts can be used as back-up in instances of recording equipment failure, but may provide a loss in concentration on recording the video takes. A technique sometime recommended is to repeat counting on another day, as counters may not be as accurate all times of the day. Counting is normally undertaken with the use of hand-held tally counters, but direct, electronic data capture systems will save time. Recording burrow counts directly to a computer with a time-stamp on each entry seems the way forward, and was developed by CEFAS.

All TV tows undertaken by England, Scotland, Ireland and Northern Ireland are intended to have a duration of 10 minutes, and longer duration was shown not to improve accuracy of abundance estimates. There is a clear reduction in the variability of counts at around 5–7 minutes duration after which it increases again. Some suggested that for high densities the tow time can be reduced, but the full 10 minutes should be taken for low densities.

A plea for Quality Control Manuals is given containing procedures for:

- handling survey equipment.
- station selection and location, as well as navigational accuracy and documentation.
- survey report writing and documentation.
- detailing the appropriate qualifications and training of survey and laboratory personnel including training for screen evaluation/counting.

A uniform data model and central repository for this category of data was recommended, but due to various laboratories using differing systems the least thing to do is to create a simplified data-exchange format.

DVD is currently the most common format for video storage although there are concerns regarding the lifespan of individual discs and it is recommended that DVDs are re-created every 1–2 years. Given the large number of DVDs generated in a single year (50 for Scotland), this becomes an increasingly burden-some task. Alternative digital formats are being tested including optical drives and server-quality hard drives.

The creation of reference datasets will make the process of inter and intra-laboratory calibration much more rigorous.

4.4 Variables affecting the abundance estimate

4.4.1 Field of view

One of the most important variables mentioned is the height of the camera (and sledge) above the sea bed, which determines the field of view. The MSS sledge uses an altimeter (range finder), enabling a calculation of mean viewed width per unit of time (typically each minute). A comparison of data by MSS showed that a precise measurement of field of view is not critical to the assessment process, providing a good approximation is made (ICES, 2007). CEFAS uses a laser scalar array mounted around the camera projecting four dots onto the seabed. This provides a scale and perspective to be able to calculate the field of view at the bottom of the TV screen at each station. MI uses a rope with markers in front of the camera to calculate the field of view. Others use a bottom grid to be superimposed over the video display.

4.4.2 Distance travelled

Distance travelled can be calculated using the ship's navigational DGPS system with additional GPS-sensors (e.g. a stand-alone Garmin 75), or more precisely using a wheel running over the sea bed (odometer). MSS uses an odometer that can be raised off the sea bed during shooting. Also it can be lowered to measure correctly in case the sledge lifts off the ground, and it is monitored with a camera. CEFAS mentioned to favour the odometer signal and both depth and warp length are also recorded at the start and end of the count. MI uses since a 2005 IXSEA GAPS (Global Acoustic Positioning System) to track, in real-time, the video sledge.

4.4.3 Recognition of Nephrops burrows

Nephrops burrows have been investigated in detail, which featured studies by divers and making them visible by making resin casts. A crescent shaped opening to a shallowly descending tunnel, with obvious linear tracks fanning out from the opening is characteristic of a *Nephrops* burrow, but not all openings to such burrows have these distinctive features. The overall mean number of openings to a *Nephrops* burrow was three. The mean maximum distance between a burrow's openings was 52 cm, the range 14–172 cm. Small *Nephrops* burrows can be mixed up with the burrows of the calocaridid mud-shrimp *Calocaris macandreae* or the burrowing crab *Goneplax rhomboides* or the goby *Lesueurigobius friesii* or the snake blenny *Lumpenus lampretaeformis* or the laomediid mud-shrimp *Jaxea nocturna* or the red band fish *Cepola rubescens*.

4.4.4 Occupancy rate of burrows

Burrows are not static or fixed, instead they 'migrate' slowly through the sediment because continuously there are new tunnels under construction and old ones in a state of collapse. Several features are indicative of occupancy (*e.g.* fresh tracks, signs of recent excavation), but these are not infallible. On the other hand partially collapsed burrow sections or debris in openings are no guarantee that a burrow is unoccupied. Depending on depth vacated *Nephrops* burrows can be taken over by other species such as black gobies (Gobius niger). Burrows can be co-occupied by more than one *Nephrops*. Burrows of adult and juvenile *Nephrops* can also be associated. CEFAS and MI planned to take time-lapse video observations of emergent *Nephrops* over a number of hours in 2007.

4.4.5 Use of electric stimulation

During the WGNEPS meeting of November 2013 the idea was suggested to use electric pulses during the UWTV-survey to stimulate *Nephrops* to leave their burrow and achieve a better estimate of occupancy rate.

4.4.6 Edge effects

Burrow counts will include burrows wholly in view of the camera and burrows that extend out of the field of view (Figure 11). Such burrows would therefore be counted again on an abutting parallel camera track. Such edge effects cause in surveys potentially overestimating density by underestimating the effective viewed area (width) of track. This is thus a potential source of bias and uncertainty. The magnitude of this effect will vary with the size of burrows and the width of view, with the effect being greater with larger burrows and narrower field of view. Modelled and empirical data suggest a similar magnitude of this effect. Edge effects are not routinely applied to assessment surveys. Modelling should be refined to provide correction factors that can be applied to the survey data. Refinements should include variations in burrow size and density. To inform modelling the edge effect, more information is required on burrow sizes from a range of grounds. Research to date suggests detection underestimates burrow density, and may compensate for edge effects (ICES, 2007).

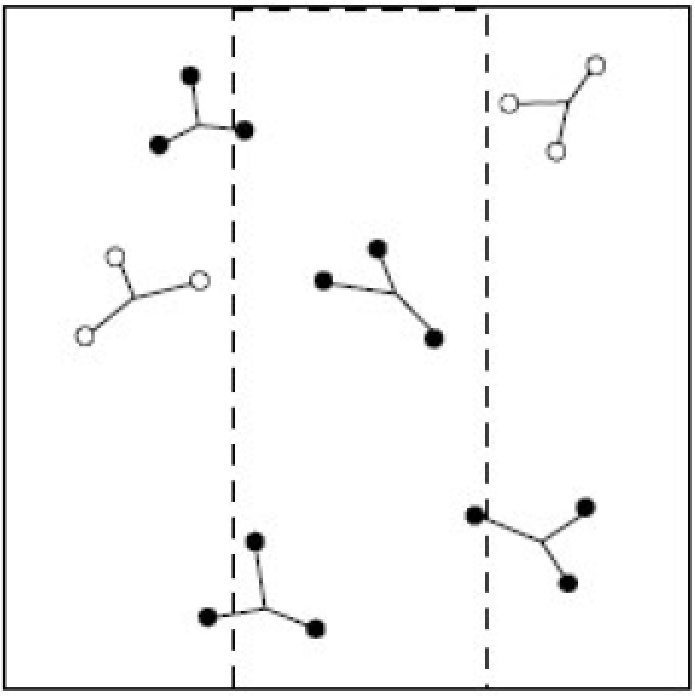

Figure 11. Pictorial simplification of the burrow counting methodology. The extent of the area of seabed viewed at a station is indicated by the dashed rectangle. Burrow systems with an opening within this area, which therefore would be counted, are indicated as solid circles. Burrow systems without an opening in the viewed area are indicated as hollow circles. Figure shows all burrows with three openings, but simulation allows number of openings to vary. Source: Fig. 6.5 (ICES, 2007).

4.4.7 Boundary uncertainty

Nephrops do not make burrows in all sediments, but favour the softer ones (mud, clay). It is therefore necessary to determine the areas which are likely to contain *Nephrops* burrows. Various acoustic survey methods e.g. multi-beam and side-scan can be used to construct more detailed maps of bathymetry and habitat type, and VMS data to confirm positions aided by ground truthing data such as using grab samples. Also there is a need to decide what kind of distinction between *Nephrops* ground and non-*Nephrops* ground is to be made. One may assume a knife-edge change in mean density at the boundaries of strata with outside the strata a density of zero, or some gradual transition. Taking into account the three-dimensional nature of the seabed did not seem to make a large difference (i.e. less than 0.0025%).

4.4.8 Estimating animal size

Various ways exist to estimate animal size, *e.g.* from video, either direct (easiest with a vertically mounted camera) or from burrow size; by using a still camera; and from trawl catches. The widths of burrow openings can be measured using *e.g.* Didger 3.0 image analysis software and related to carapace length. Available data suggest that burrow size increases with animal size. Most of the other institutes involved in UWTV surveys include tows with a small (2m wide) beam trawl to estimate the length distribution per location.

4.4.9 Estimation of biomass

For estimating the biomass one needs estimates of burrow abundance and an assumption of burrow occupancy rate and that the length frequency distribution *Nephrops* can be estimated from the dimensions of the burrows, and that the average weight of an individual can be estimated from the length frequency distributions. In addition it requires knowledge or an assumption about the population sex ratio, given that the length-weight relationship is steeper for males than for females and that males grow larger than females. Trawl samples can be used to determine the sex ratio (at length), but the following assumptions underlie this: selectivity ogives and emergence rates are the same for males and females. The latter assumption is not always true as females tend to stay in their burrows when hatching eggs, but when fishing at other periods than the reproductive ones the assumption may be valid.

Nephrops caught in the fishery (landings + discards) may exclude small animals that may nevertheless be large enough to make burrows, as they pass through the meshes or under the ground rope of the net. UWTV surveys refer to animals that have made burrows, which are counted. The very small (0-group) *Nephrops* do not have their own burrows and are thus not included in the UWTV survey counts, but still form part of the stock biomass. So these are missed by either two methods of retrieving data. *Nephrops* trawl surveys may use sampling gear of smaller mesh size than the commercial gears, and take a larger proportion of juveniles.

4.5 Raising procedures

Raising procedures deal with how to get from burrow counts from a UWTV-survey or trawl sampling data to total abundance estimate? The first problem is to get the counts from video or photographic information. One can decide to filter out images with a very small (*e.g.* < 1 m^2) or very large (*e.g.* > 16 m^2) readable area to avoid problems with pixel resolution and object sizes. The loss of footage will nevertheless be limited, typically not more than 5% fall in this category.

Usually stratification is used based on sediment type. Burrow openings of each stratum are counted. For any given stratum, the mean density of burrow openings and its associated variance are estimated. For each stratum the abundance is calculated as a product of average density and the area of the stratum. The numbers are then summed to the total survey area. Then 95% confidence limits are calculated from the sum of the stratum variance. MSS has developed an R code for calculating burrow densities, which is given in Appendix B. An additional sequence of R code takes the output of the burrow density calculation routine and returns a vector giving the stratum to which each calculated density value belongs.

UWTV technologies can also be used to in conjunction with trawl surveys. Two approaches exist one using UWTV surveys observations to standardized trawl catches, the other using a headline mounted camera to estimate catchability during a trawl survey.

4.5.1 Sources of uncertainty

The level of uncertainty depends on the use of the calculated indices in the assessment, as a trend in abundance, or as an absolute abundance estimate, which would be the most uncertain application, or as a relative index of burrow abundance to tune an assessment with catch data. An appropriate size distribution, and the relationship with the size distribution of the overall population are needed to calculate biomass.

The harvest ratio process uses the survey as an estimate of absolute abundance, and includes an additional assumption that the size distribution of the exploited population in recent years reflects future exploitation patterns. Due to uncertainties and bias in catch data for this stock this approach currently provides the best available basis for management advice.

Important variables when using the survey for a relative index of burrows abundance:

- Field of view
- Length of tow
- Burrow detection
- Burrow identification
- Edge effects

For estimating absolute numbers:

- Burrow occupancy (100% assumed)
- Area or boundary uncertainty
- Numbers outside survey area

And for absolute biomass estimate:

- Size distribution of animals contributing to burrow estimate
- Sex distribution as above
- Additional biomass of animals not covered above
- Biomass outside survey area

Initially the harvest ratio approach took a rate of 7.5% of the total TV abundance in numbers averaged over the previous 3 years to calculate a TAC, deemed to be a conservative value. This is then converted into a biomass by distributing according to the observed length-frequency distribution of the recent catch (3 year average from market sampling and discard data with 75% discard mortality) and applying an appropriate length-weight relationship. The landed portion of this biomass is then used to give a TAC, assuming that the size distribution of catches in the TAC year did not change from recent years. The ratio of landings and TV survey abundance biomass can be averaged over some period, but if stocks are data poor this will give an underestimate. In accordance with a fishing mortality of 10% ($F_{0.1}$) a harvest ratio of 20% was chosen in 2005. This was later converted into a (sex) harvest ratio of 20% representing fishing mortalities between $F_{0.1}$ and F_{max}.

4.6 Other use of a *Nephrops* UWTV survey

The survey can be used for other eco-system related purposes and assessment, e.g. to collect data and footage on: epifauna general, trawl marks, sediment structures, video, photo, sonar, sediment chemistry, sediment composition, and information on other benthos.

4.7 Other options

A camera can be placed on the headline of a trawl with underwater lighting, as is done by IPIMAR (Figure 12). The device has an autonomous underwater video recorder, without the need for an electrical feeding cable. Using a headline height sensor (*e.g.* SCANMAR) one can determine the height above the sea bed. This seems a relatively cheap alternative. Another advantage is that the number of burrows can be compared with total catches for each trawl for calibration purposes. A drawback is that some loss of fishing time may occur, due to more careful shooting and hauling. The headline height of trawls will vary in practice which will have an effect on the field of view. In addition trawl catches will not cover both species at equal rates, as females tend to stay inside the burrow. Another disadvantage of autonomous recording systems is that data is not real-time available, and its processing requires extra time and labour costs.

Figure 12. Headline camera used by IPIMAR; from: (ICES, 2007).

4.8 Possibilities for improvements.

In 2007 several problems with regard to the survey where mentioned (ICES, 2007). When the new CRR is out these items need to be checked again.

Problems mentioned are logistic as well as related to the methodology (ICES, 2007):

- Costs for investment, insurance and maintenance are high.
- Fishing activity can obscure visibility and require stations to be resituated.
- Considerable time needs to be invested in training staff in handling the sledge and video interpretation. Reviewing the footage can have some associated problems, including: consistency in burrow identification for an individual and between reviewers.
- Calculating the field of view and edge effects. Field of view estimates and distance run are vital to calculate the density of burrows. Field of view for CEFAS surveys is estimated just below the surface using a calibration screen and this estimate is applied to the counts at each station. Applying a real time estimate of field of view to account for this sinking as well as the lifting mentioned earlier could provide more accurate estimates of burrow density.
- Accuracy of the distance over ground covered by the sledge.
- Towing speed can reduce the details observed.
- Clarity or turbidity of the water.
- Weather induced motion. Swell and waves will affect how well the sledge stays in contact with the seabed. Any lifting will affect the field of view and at its extreme the view can be clear of the seabed. Video footage from tows crossing or following a previous sledge track show that the sledge does settle into the sediment and evidence from FRS shows that the height of the camera from the seabed can vary considerably over a survey. currents on the seabed might be extremely strong, e.g. in the Irish Sea. The survey is often scheduled during periods of neap tides and regularly stations are visited on more than one occasion if the visibility is not good enough. The sledge is reported to perform well up to wave heights of around 2.0 m.
- Burrows counts can be overestimated due to confusion with other species burrows, uncertainty may arise in identifying burrows belonging in a same system, the occupancy rate is unknown. There may be inter-reader variability as different reviewers may come up with different counts.
- Limitations in the umbilical or signal transmitting wires. Cores in the umbilical can all be used by the camera and lighting system preventing the addition of sensors to measure camera height, roll and pitch, turbidity etc. or allow for the addition of a grab on the sledge. This may also allow for the operation of one camera system at a time. Upgrading to a slip-ring winch, fibre-optic load bearing umbilical cable and associated topside and sub-sea equipment for the sledge-mounted underwater TV system. This will allow for multiple cameras (up to 3) and the addition of various sensors to calibrate field of view more accurately.
- Deployment and recovery is laborious for the deck crew and there are concerns in terms of health and safety.
- The resolution might be too poor for higher taxonomic ID at towing speeds around 1 kn; tow duration is normally 5 to 10 minutes.
- Even distribution of lighting on the seabed, penetration of lighting on the seabed.
- For image analysing purposes a grid should be computed and subsequently superimposed onto the images. However, the lack of exact height parameters affects both the accuracy and precision of all measurements obtained from individual video frames. It would, thus, be useful to have time stamped information on the height of the UWTV equipment above the seabed. The smear effect when images are captured at higher speeds (of around 2.8 knots) may also hinder image analysis.

Suggestions for improvement were also given(ICES, 2007):

- It was recommended by Marine Science Scotland (MSS) that a 10 minute sacrificial run is reviewed before final interpretation of footage is carried out; this helps the reviewer 'tune in' to the task before beginning on data that will be used in the assessments.
- MSS has introduced a key as to how to grade the water clarity. This provides a quantifiable field when reviewer calibration work is carried out, and may help explain anomalous counts, but needed to be refined.
- Use a forward-looking camera to calibrate this survey with other stock surveys.
- Avoid using a single COAX in the video transmitting cable. Although a video signal was boosted through twisted pairs, but take a lighter Kevlar/polypropylene cable (dual coax or fibre optic).
- Avoid paying out too long a cable as it may drag in the sediment, which affects visibility. If the cable is too short the surface movement or lift is transferred directly to the sledge and then the vessel's movement would become more apparent.
- Use a laser array and a way for sighting an altimeter at camera height to provide a better real time estimate of field width.
- Apply a full towing umbilical and slip ring winch using a load bear fibre optic cable and sub-sea multiplexing to allow integration with existing cameras and light systems. This would greatly reduce deployment and retrieval time, and will also allow for the capability to add further electronic units as UWTV technology develops.
- Mount a self-powered and recording CTD sensor on the sledge to collect fine resolution oceanographic data during surveys.
- It was acknowledged that here is scope for improved data management and validation for UWTV surveys. This might be achieved by integrating the video, navigation and other datasets in a GIS framework which would allow quick data access and visualization.
- Always use an odometer and range finder to the AFBI sledge to improve the accuracy of the area viewed estimates.
- Fit a light meter to the frame.
- Consider replacement of the sledge system with an Autonomous Underwater Vehicle (AUV)system for large area measurements, and allow the vessel to simultaneously undertake other work. This would have several advantages but may involve substantial investment costs (starting at 250k€) depending on vehicle type (depth/duration).
- Use higher specification cameras (higher resolution, low blurring) multiple cameras, image enhancement (*e.g.* Lyyn T-38 real time video enhancer), different lighting solutions (halogen, HID, LED, infrared) and greater instrumentation of the sledge.
- Add turbidity sensors and field of view sensors (height, roll and pitch) on the sledge.
- Use a Doppler velocity log (DVL) that can be highly accurate for position, distance and direction moved, instead of a mechanical odometer.
- Use fibre optic cable systems that allow a considerable increase in transmission bandwidth while decreasing the diameter of the cable. Such bandwidth allows for almost unlimited sensor data to be transmitted (multiple cameras and other sensor data). However the termination of such systems is not always possible undertake at sea (damage repair) and the cost and complexity of the system is high (*e.g.* cost of optical slip-rings in the winch).
- Consider the use of sonar technologies for high-resolution ground penetrating systems enabling visualization of areas of sediments with tens of centimetres penetration. This may allow the visualization of *Nephrops* burrow systems.
- Consider the use of video image processing technologies (*e.g.* IFREMER's Matisse software).
- New technologies for data management are constantly evolving *e.g.* web-GIS and ARC-marine GIS platform which might make accessibility of historical data and footage easier.

5. Costs for a survey of the areas Off Horn's Reef and Botney Gut-Silver Pit

5.1 Introduction

The possibility of setting-up a new survey depends of course on available funding and costs involved. *Nephrops* survey experts were contacted by e-mail and during the ICES WGNEPS meeting in Barcelona in November 2013 to retrieve information on the inputs in terms of person-hours, equipment costs, vessels costs in relation to FU surveyed and the number of stations involved in the survey. From this we worked out the inputs per station covered.

The next step was to estimate the number of stations needed in the areas to be surveyed, *i.e.* Off Horn Reef and Botney Gut. A recent report of CEFAS mentioned 54 stations in the Botney Gut - Silver Pit area. The duration of surveying this area was about 5 days (Appendix G).

Three options were worked out with differing staff involved, suppliers of the research vessel, the winch and cable and the TV sledge with instrumentation (Table 3).

Table 3. Role division and suppliers in the various options.

Option	IMARES staff	Institute's staff	Sledge with instruments	Winch with cable	Vessel supplier	Training by	Meetings
1	6	1	IMARES	NL Ministry	NL Ministry	UK institute	at IMARES
2	4	2	UK institute	NL Ministry	NL Ministry	UK institute	both
3	4	6	UK institute	UK Ministry	UK Ministry	UK institute	both

5.2 Investment costs

The total minimal investment is estimated at **€ 97400** for the equipment *i.e.* the sledge itself with instrumentation and a deck unit (Table 4), spares at **€ 63400** (Table 5). The costs for the winches and cables on the research vessel are estimated at **€ 204000** (Table 4). These estimated are based on a similar system as used by CEFAS and MSS in the UK.

*Table 4. Minimum set of equipment to invest in for a UWTV Nephrops surveys. Blue is optional, but these parts could also be useful for other benthos related programmes. Items with * are optional. All amounts are exclusive of VAT.*

Item	Parts	Type	Quantity	Estimated costs IMARES (€)	Estimated costs vessel owner (€)
Sledge	Sledge (aluminium)		1	1500	
	Underwater video camera	OE14-366	1	5000	
	Multiplexer receiver/transmitter	Nexus MK V	1	45000	
	Underwater laser		6	1200	
	Underwater LED light		5	1000	
	Odometer		1	2000	
	Mounts for camera's and parts		1	1200	
	Rangefinder		1	4000	
	Underwater connectors & tails		1	5000	
	Stills camera & flash*		1	18000	
	Grab, Grab motor & housing*		1	3300	
	Rear video camera		1	3000	
	Battery and housing		1	1200	
Winch/cable	Underwater main cable umbilical (600 m)		2		42000
	Cable winch with controls in dry-lab & wheelhouse		1		160000
	Cable deck guidance blocks		2		2000
Deck unit	Video observation monitors		2	1000	
	Video overlay for DGPS & Time		1	2000	
	DVD recorders		2	1000	
	Video enhancement LYNN tool		1	2000	
Total investment IMARES				**97400**	
Total investment vessel owner					**204000**

Table 5. Minimum set of spare equipment to invest in for a UWTV Nephrops surveys. All amounts are exclusive of VAT.

Item	Parts	Type	Quantity	Estimated costs (€)
Sledge	Sledge (aluminium)		1	1500
	battery and housing		1	2000
	Underwater video camera	OE14-366	1	5000
	Multiplexer receiver/transmitter	Nexus MK V	1	45000
	Underwater LED light		5	1000
	Underwater laser		6	1200
	Odometer		1	2000
	Mounts for camera's and parts		1	1200
Winch/cable	Underwater main cable umbilical (500 m)		1	
	Cable winch		0	
	Slipring set		0	
	Cable deck guidance blocks		1	1000
	Underwater connection parts & tails		1	3000
Deck unit	Video observation monitors		0	
	Video overlay for DGPS & Time		0	
	Video storage		1	500
Total spares IMARES				**63400**

5.3 Expected survey costs

Initially we have sent an inventory to a list of experts to determine costs indices, such as total survey costs, survey costs per number of stations, and staff hours per number of stations. The response rate was relatively low, but values were sent in by CEFAS and the Irish MI. An overall first estimate of survey costs is € 1000 per station (Appendix A). The three options calculated below give a first estimate of costs under various scenarios. They are based on several assumptions and would need further refinement before making a final choice.

5.3.1 Option 1 - Survey carried out by IMARES with CEFAS participating and using own equipment.

This option features that the survey is done on a Dutch RV involving 6 staff members (4 assistants, 1 junior scientist and 1 senior scientist) from IMARES, and 1 scientist from the other institute to train the IMARES staff in the first two years, after which it is assumed that IMARES staff is able to run the survey by themselves. The number of staff is based on a 24 hour operation. A continuous day and night cycle is required to cover both the day and night behaviour *Nephrops* with its effect on catchability and abundance. The sea time for the survey is estimated at 16 days per year (Table 6). Furthermore the analysis is done by IMARES staff only, but staff undergoes training by *e.g.* CEFAS, estimated with third party costs at € 4915 in the first year. It is assumed that investments on a sledge and instrumentation are made by IMARES, but a suitable winch and cable will have to be installed on a Dutch RV, paid by the Dutch Ministry. All project meetings are held at IMARES, with no involvement of other institutes. The burrow counting and qualification is calibrated among staff of other institutes aimed at improving accuracy and reducing misinterpretation. In this proposal participation of staff on other surveys has been included. IMARES participates fully in WGNEPS with 1 junior scientist and 1 senior scientist.

Table 6. Survey scheme RV "Tridens" in Option 1

Day	Activity	Distance (nm)	Ground	No. of stations	Sum per area
1	loading and steaming	130			
2	setting up equipment		Botney left		
3	survey		Botney left	20	
4	survey		Botney left	20	
5	survey		Botney left	20	**60**
6	survey		Botney right	20	
7	survey		Botney right	20	
8	survey		Botney right	20	**60**
9	steaming	150			
10	survey		Horn top	20	
11	survey		Horn	20	
12	survey		Horn	20	
13	survey		Horn	20	
14	survey		Horn bottom	20	**100**
15	steaming to port	150			
16	port unloading				

RV “Tridens” is only 50% allocated, and could be available for this survey. Training must be organised, either by joining other cruises or inviting experts from other institutes. We believe that RV “Isis” is not suitable for this task, because she is very sensitive to rough seas and the risk of drawback due to bad weather is too high. There is enough space on-board for the personnel needed (6), and for invited experts (1 or more). The place for the cable winch should be identified, and its purchase and installation be properly guided, including cable guidance and blocks. This requires a person from IMARES to have intensive contact with the vessel owner (“de Rederij”).

With the initial investment the costs for IMARES’ involvement will be about **450 k€** in the first year and **233-213 k€** in the following years. In addition there is an investment in a winch and a cable of **204 k€** and vessel costs (based on RV “Tridens” at 17.5 k€ per day) of **280 k€** needed by Ministry EZ (Table 7). Included there are staff costs of £500 (€594) for a technician and £600 (€713) for a scientist based on CEFAS labour rates (Info Ana Leocadio, 13/12/2013).

Table 7. Cost estimate for Option 1, survey done by IMARES with CEFAS participating and using own equipment.

Costs for Option 1, VAT excluded

Material costs IMARES	Item	Year	Total (€)	Year	Total (€)	Year	Total (€)	Item	Total Costs (€)
	Materials	2014	160800	2015	0	2016	0	Materials	160800
	Travel & subsistence	2014	9400	2015	9027	2016	9208	T & S	27635
	Third parties	2014	39376	2015	35122	2016	11225	Third parties	85723
	Total	2014	209576	2015	44149	2016	20433	Total	274158

Personal costs IMARES	Function Category	2014 Hours	2014 Costs (€)	2015 Hours	2015 Costs (€)	2016 Hours	2016 Costs (€)	Total Hours	Total Costs (€)
	Senior Scientist	558	66960	478	58507	478	59677	1514	185145
	Junior Scientist	810	77760	542	53073	542	54134	1894	184967
	Assistent	1240	95480	984	77283	984	78829	3208	251592
	Total	2608	240200	2004	188863	2004	192640	6616	621704

Total IMARES (€)		
	2014	449776
	2015	233012
	2016	213073
	Sum	895862

	Total Costs (€)
Total IMARES	895862
Investment EZ	204000
Vessel costs EZ	280000

5.3.2 *Option 2 - IMARES carries out the survey with CEFAS on a Dutch RV using the UK sledge.*

In this option the survey is done with e.g. CEFAS (or MSS) on a Dutch RV involving 4 staff members (2 assistants, 1 junior scientist and 1 senior scientist) from IMARES, and 4 researchers from the other institutes joining this survey (2 technicians and 2 scientists) during all the three years. The number of staff is based on a 24 hour operation. A continuous day and night cycle is required to cover both the day and night behaviour *Nephrops* with its effect on catchability and abundance. The sea time for the survey is estimated at 19 days per year (Table 8). The survey time is extended by 2 days in order to enable loading the equipment in a UK port. The analysis is done by IMARES staff and the other institute’s staff, and IMARES staff undergoes training by e.g. CEFAS, estimated with third party costs at € 4915. It is assumed that investments on a sledge and instrumentation are not needed as the other institute will supply this, but a suitable winch and cable still have to be installed on a Dutch RV, paid by the Dutch Ministry. Project meetings are held at IMARES and the other institute’s venue. IMARES participates fully in WGNEPS with 1 junior scientist and 1 senior scientist.

Table 8. Survey scheme RV "Tridens" in Option 2

Day	Activity	Distance (nm)	Ground	No. of stations	Sum per area
1	steaming to Lowestoft	90			
2	loading equipment and steaming	120			
3	setting up equipment		Botney left		
4	survey		Botney left		
5	survey		Botney left	20	
6	survey		Botney left	20	
7	survey		Botney left	20	**60**
8	survey		Botney right	20	
9	survey		Botney right	20	
10	survey		Botney right	20	**60**
11	steaming	150			
12	survey		Horn top	20	
13	survey		Horn	20	
14	survey		Horn	20	
15	survey		Horn	20	
16	survey		Horn bottom	20	**100**
17	steaming to Lowestoft	210			
18	port unloading				
19	steaming to Scheveningen	90			

No buffer was allocated in the ship time because of budget constraints. The survey itself is again based on a 24 hours operation (staff 7 persons, minimum 6, and all analysis is done on-board). Five stations should also be fished with a 2 m beam trawl in 2011. Other comments are that vessel time can be a problem, as the CEFAS programme is 95% fixed. As the survey areas are in the middle of the North Sea, the use of small vessels can be a problem.

With the initial investment this options will cost **279 k€** for IMARES work in the first year and about **241-243 k€** in the following years (Table 9). Included there are staff costs of £500 (€594) for a technician and £600 (€713) for a scientist based on CEFAS labour rates, including travel and subsistence when visiting the Netherlands (Info Ana Leocadio, 13/12/2013). In addition there is an investment in a winch and a cable of **204 k€** and vessel costs (based on RV “Tridens” at 17.5 k€ per day) of **332.5 k€** needed by Ministry EZ.

Table 9. Cost estimate for Option 2, survey done by IMARES with CEFAS on a Dutch RV using the UK sledge.

Costs for Option 2, VAT excluded

Material costs IMARES	**Item**	**Year**	**Total (€)**	**Year**	**Total (€)**	**Year**	**Total (€)**	**Item**	**Total Costs (€)**
	Materials	2014	0	2015	0	2016	0	Materials	**0**
	Travel & subsistence	2014	9150	2015	8976	2016	9156	T & S	**27282**
	Third parties	2014	67334	2015	63639	2016	62164	Third parties	**193137**
	Total	**2014**	**76484**	**2015**	**72615**	**2016**	**71320**	**Total**	**220419**
Personal costs IMARES	**Function Category**	**2014 Hours**	**2014 Costs (€)**	**2015 Hours**	**2015 Costs (€)**	**2016 Hours**	**2016 Costs (€)**	**Total Hours**	**Total Costs (€)**
	Senior Scientist	582	69840	514	62914	514	64172	**1610**	**196925**
	Junior Scientist	774	74304	578	56598	578	57730	**1930**	**188631**
	Assistent	752	57904	624	49009	624	49989	**2000**	**156902**
	Total	**2108**	**202048**	**1716**	**168520**	**1716**	**171891**	**5540**	**542459**

Total IMARES (€)	**2014**	**278532**			**Total Costs (€)**
	2015	**241135**		**Total IMARES**	**762878**
	2016	**243211**		**Investment EZ**	**204000**
	Sum	**762878**		**Vessel costs EZ**	**332500**

5.3.3 *Option 3 - IMARES carries out the survey with CEFAS on a British RV using the UK sledge.*

In this option the survey is done with *e.g.* CEFAS (or MSS) on a British RV involving 4 staff members (2 assistants, 1 junior scientist and 1 senior scientist) from IMARES, and 6 researchers from the other institutes joining this survey (4 technicians and 2 scientists) during all the three years. The number of staff is based on a 24 hour operation. A continuous day and night cycle is required to cover both the day and night behaviour *Nephrops* with its effect on catchability and abundance. The reason that for this option more staff is taken into account then in the other options is is because the other institute runs their usual survey with 6 people. The IMARES staff is taken somewhat higher to enable learning. The sea time for the survey is estimated at 17 days per year (Table 10). The analysis is done by IMARES staff and the other institute's staff, and IMARES staff undergoes training by *e.g.* CEFAS, estimated with third party costs at € 4915. It is assumed that investments on a sledge and instrumentation are not needed as the other institute will supply this, including a suitable winch and cable, so there are also no costs for these items for the Dutch Ministry of Economic Affairs. Project meetings are held at IMARES and the other institute's venue. IMARES participates fully in WGNEPS with 1 junior scientist and 1 senior scientist.

Table 10. Survey scheme RV "Endeavour" in Option 3

Day	Activity	Distance (nm)	Ground	No. of stations	Sum per area
1	loading equipment and steaming	120			
2	setting up equipment		Botney left		
3	survey		Botney left		
4	survey		Botney left	20	
5	survey		Botney left	20	
6	survey		Botney left	20	**60**
7	survey		Botney right	20	
8	survey		Botney right	20	
9	survey		Botney right	20	**60**
10	steaming	150			
11	survey		Horn top	20	
12	survey		Horn	20	
13	survey		Horn	20	
14	survey		Horn	20	
15	survey		Horn bottom	20	**100**
16	steaming to Lowestoft	210			
17	port unloading				

The best expertise seems to be within MI, MSS, and CEFAS. CEFAS (and MSS) use the same winches, cables, and frames, which will make collaboration with these partners easier. This option makes the survey dependent on the other institute in terms of research vessel, equipment and staff availability. The CEFAS programme is 95% fixed so leave hardly no opportunity for additional obligations.

This option will cost about **579 k€** for IMARES work in the first year and about **563-574 k€** in the following years (Table 11). Included there are vessel costs (based on RV "Endeavour" at £15000 (€17826) per day) of **303 k€** yearly and staff costs of £500 (€594) for a technician and £600 (€713) for a scientist based on CEFAS labour rates, including travel and subsistence when visiting the Netherlands (Info Ana Leocadio, 13/12/2013).

Table 11. Cost estimate for Option 2, survey done by IMARES with CEFAS on a UK RV using the UK sledge.

Costs for Option 3, VAT excluded

Material costs IMARES

Item	Year	Total (€)	Year	Total (€)	Year	Total (€)	Item	Total Costs (€)
Materials	2014	0	2015	0	2016	0	Materials	0
Travel & subsistence	2014	10717	2015	10778	2016	10994	T & S	32489
Third parties	2014	386000	2015	388678	2016	396424	Third parties	1171102
Total	2014	396717	2015	399456	2016	407418	Total	1203591

Personal costs IMARES

Function Category	2014 Hours	2014 Costs (€)	2015 Hours	2015 Costs (€)	2016 Hours	2016 Costs (€)	Total Hours	Total Costs (€)
Senior Scientist	542	65040	498	60955	498	62174	1538	188170
Junior Scientist	674	64704	562	55031	562	56132	1798	175867
Assistent	680	52360	600	47124	600	48066	1880	147550
Total	1896	182104	1660	163110	1660	166372	5216	511587

Total IMARES (€)	2014	578821
	2015	562566
	2016	573790
	Sum	1715178

	Total Costs (€)
Total IMARES	1715178
Investment EZ	0
Vessel costs EZ	0

Each of the three options has advantages and disadvantages and the level of risk may differ (Table 12). A choice will depend on how one weighs these aspects.

Table 12. Strengths, weaknesses and risks of the options studied.

Option	Total costs in 3 years in (k€)	Strengths	Weaknesses	Risk
1	IMARES & third party: **896** EZ materials: **204** EZ vessel: **280**	Cheapest option when vessel costs, winch, blocks and cables are covered by the vessel owner! These can also be used for other related tasks. Build-up of own expertise and independence. Use of a large vessel able to operate in adverse conditions. Other tasks (benthos projects) can likely be integrated. The option enables an improved use of this RV.	Part of the equipment needs to be purchased and maintained by EZ. Vessel may be difficult to operate at very low speeds. We may need dynamic positioning (DP).	FRV time needs to be allocated, but the risk is low as the Dutch FRVs are not fully booked. Funds may be lacking.
2	IMARES & third party: **763** EZ materials: **204** EZ vessel: **332.5**	No investment on own sledge and instrumentation.	Dependent on equipment by others, and risk of having to replace this in case of loss. The sledge is not available for other work.	Winch and cable cannot be used for other purposes. Funds may be lacking. In case of loss or damage of institute's equipment IMARES should replace or repair it.
3	IMARES & third party: **1715** EZ materials: **0** EZ vessel: **0**	No investment on own sledge and instrumentation. Fully building on the expertise of others.	Fully dependant on others for the survey, both in terms of vessel and equipment. Initially the IMARES staff may not be able to run the survey without experience. Vessels have not a flexible agenda for extra work (95% yearly coverage) and needs to be hired and is not paid by Ministry EZ.	<u>Low in terms of equipment, that is already in use.</u> <u>Vessel may not be available.</u> Funds may be lacking. In case of loss or damage of institute's equipment IMARES should replace or repair it.

6. Conclusions and recommendations

The methodology and technology of a UWTV-survey on *Nephrops* are well developed and documented within ICES. When setting-up a new or extended survey, this information can and should be used.

A UWTV-survey is preferred over a survey using a headline unit on commercial fishing gears. It will supply a fisheries independent abundance estimate, and has developed into a standard method within ICES.

Given the relative large distances that have to be covered and the remoteness of the two survey areas it is recommended to use a vessel that can sail at fairly high speeds and forms a stable working platform. In addition the vessel should be able to sail at very low speed with precision.

As the CEFAS institute is involved in one of the survey areas (Botney Gut) sharing the survey costs with another participant seemed a logical choice. However, the operational risks in particular concerning the availability of vessels are high and vessel costs need to be considered, while the Dutch RV “Tridens” is only used 50% of the time on an annual basis. In addition it appeared from communications with CEFAS, that additional funding will be needed to extent their survey programme.

Option 2 using another institute’s equipment is the cheapest option, compared to using RV “Tridens” with participation of foreign expertise and training of IMARES staff, or hiring a foreign research vessel with accompanying foreign expertise. It should be noted that vessel hire and/or equipment such as: winch, blocks and cables should be covered by the Ministry of Economic Affairs.

Initially the costs are relatively high, but in later years when staff has been trained and equipment developed these costs will be substantially lower.

The *Nephrops* survey may also be used to retrieve additional data, and can possibly be extended to other purposes. A UWTV sledge can in principle also be used to support other tasks, e.g. viewing the sea bed or taking samples from the sea bed in other surveys. Option 1 also avoids the risk of having to invest in replacement or repair of equipment owned by others in case of loss or damage.

When investing in own equipment and expertise dependency of others will be avoided. Only this way IMARES will be able to fully participate as a full partner in ICES WGNEPS.

The final choice will depend on available funding for a *Nephrops* survey. If Option 1 can be financed then a detailed working plan can be defined.

We recommend to keep and maintain the UWTV sledge and instrumentation within IMARES if the choice is for investing in this, and the winch, cable and cable blocks within the vessel owner. In addition investment in a list of spare parts should be made to avoid that the work cannot be continued in case of malfunctioning, damage or even loss of equipment.

When building up equipment and instrumentation it should and can be considered to use the latest and highest standard in technology.

7. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

References

Anonymous, 2013. Nephrops (Norway lobster). The Scottish Government, Edinburgh.

de Haan, D., 1998. De mogelijkheden van een acoustische remote sensing techniek (QTC) voor detectie van schelpdieren. (In Dutch). RIVO Report C031/98.

Howard, F.G., 1989. The Norway Lobster. Scottish Fisheries Information Pamphlet, No 7. ISSN 0309 9105. p. 18.

ICES, 2000. Report of the Study Group on the Life History of Nephrops. ICES 2000 CM:G06., 151.

ICES, 2007. Workshop on the Use of UWTV Surveys for Determining Abundance in Nephrops Stocks throughout European Waters. 17–21 April 2007, Heraklion, Crete, Greece. ICES CM 2007/ACFM:14, 198.

ICES, 2013. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). ICES CM 2013/ACOM:13. Chapter 3. Nephrops in Subareas IIIa and IV.

Steenbergen, J., van der Hammen, T., 2011. Kennisdocument Noorse Kreeft (*Nephrops norvegicus*). (In Dutch). IMARES Report C091/11, 23 pp.

Tuck, I.D., Chapman, C.J., Atkinson, R.J.A., Bailey, N., Smith, R.S.M., 1997. A comparison of methods for stock assessment of the Norway lobster, Nephrops norvegicus, in the Firth of Clyde. Fisheries Research 32, 89-100.

Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Ir. J. Steenbergen
Biologist

Signature:

Date: 1 May 2014

Approved: Dr. ir. N.A. Steins
Head of department Fishery

Signature:

Date: 1 May 2014

Appendix A. Survey inventory

Country	FU	FU name	total area (km2)	# stations	vessel	vessel costs/d (€)	# survey days/y	# sci	# tech	days prep tech/y	days prep sci/y	days travel tech/y	days travel sci/y	days sea tech/y	days sea sci/y	days data tech/y	days data sci/y	**days total tech/y**	**days total sci/y**
UK Scot	7	Fladen	28153	71	Scotia														
	8	Firth of Forth	915	46	Clupea														
	9	Moray Firth	2195	45	Clupea														
	10	Noup	400	6	?														
	11	North Minch	1775	37	Scotia														
	12	South Minch	5072	34	Scotia														
	13	Clyde	2083	40	Scotia														
UK Eng	5	Botney Gut & Silver Pit	1000	43	Endeavour	combined with FU6	~3 out of 11												
UK Eng	6	Farn Deeps	2750	108	Endeavour	5000	10	7	1	2	6	0	0	11	77	0	15	**13**	**98**
UK Eng	6	Farn Deeps	2750	108	Endeavour	5791	10	7	1	2	6	0	0	11	77	0	15	**13**	**98**
UK combined NI survey	14	Eastern Irish Sea	1043	36	Corystes	survey run by NI "RV Corystes"	~ 3 days out of 7												
UK NI?	22	Smalls	2800	91	0														
IE	15	Irish Sea West	5331	145	Corystes/Celtic Voyager	8000	10	2	4	0	2	2	4	40	20	10	13	**52**	**39**
	17	Aran Grounds	926	74	Celtic Voyager														
	19	SW & South of Ireland	1572	35	Celtic Voyager														
DK	3..4	Kattegat & Skagerrak	9842	72	Havfisken?														
SE																			

Country	FU	FU name	durable equipment (€)	depreciation durable equipment (€)	consumables and computer costs (€)	maintenance costs/y (€)	vessel costs/y (€)	staff costs (including sea allow-ances) (€)	travel costs/y (€)	**total survey costs/y (€)**	total survey costs/d (€)	**total survey costs/ station (€)**	**total tech h/ station**	**total sci h/ station**	Comments	Conversion rate
UK Scot	7	Fladen														
	8	Firth of Forth														
	9	Moray Firth														
	10	Noup														
	11	North Minch														
	12	South Minch														
	13	Clyde														
UK Eng	5	Botney Gut & Silver Pit														
UK Eng	6	Farn Deeps			250	2000	50000	48400	0	**100650**	10065	**932**	**0.96**	**0.19**	All values in GBP	1.158
UK Eng	6	Farn Deeps			290	2316	57906	56053	0	**116564**	11656	**1079**	**0.96**	**0.19**	in €	1
UK combined NI survey	14	Eastern Irish Sea														
UK NI?	22	Smalls														
IE	15	Irish Sea West	22000	3300	1500	5000	80000	38900	920	**129620**	12962	**894**	**2.87**	**0.11**		
	17	Aran Grounds														
	19	SW & South of Ireland														
DK	3..4	Kattegat & Skager-rak														
SE																

Appendix B. R-code to work up TV-densities

```
#############################
##            TV Density Work-up              ##
##################nc#17.3.07##

tv.workup <- function(working.dir, index.file){
## sets up function
file.list <- readLines(paste(working.dir, index.file, sep="/" ))
## reads in index file
cruise <- file.list[1]
functional.unit <- file.list[2]
front.height <- as.numeric(strsplit(file.list[3],
split=",")[[1]][1])
back.height <- as.numeric(strsplit(file.list[3],
split=",")[[1]][2])
rangefinder.height <- as.numeric(strsplit(file.list[3],
split=",")[[1]][3])
camera.length <- as.numeric(strsplit(file.list[3],
split=",")[[1]][4])
horizontal.angle <- as.numeric(strsplit(file.list[3],
split=",")[[1]][5])
vertical.angle <- as.numeric(strsplit(file.list[3],
split=",")[[1]][6])
camera.angle <- acos((back.height - front.height)/
camera.length)*(180/pi)
height.differential <- (front.height-rangefinder.height)/100
lower.edge.view <- camera.angle-(0.5*vertical.angle)
no.stations <- as.numeric(file.list[4])
## reads in sledge parameters from the index file header
file.list <- file.list[5:length(file.list)]
file.list <- file.list[file.list!=""]
if(is.na(cruise)){
print("There are problems with your index file - please check it is
of standard format and try again")
break
}
if(sum(is.na(c(front.height, back.height, rangefinder.height,
camera.length, horizontal.angle, vertical.angle, camera.angle,
height.differential, no.stations)))>0){
print("The values for sledge parameters have not been correctly
formatted, check your file and try again")
break
}
if (length(file.list)==2*no.stations){
print("CORRECT NUMBER OF FILES IN INDEX")
}
if (length(file.list)!=2*no.stations){
print("INCORRECT NUMBER OF FILES IN INDEX")
```

```
break
}


## some quality control checks
lats <- vector(length=length(file.list)/2)
lons <- vector(length=length(file.list)/2)
average.densities <- vector(length=length(file.list)/2)
counter.1.densities <- vector(length=length(file.list)/2)
counter.2.densities <- vector(length=length(file.list)/2)
## sets up vectors to hold outputs
if(file.exists (paste(working.dir, "Diagnostic Plots", sep="/")) !=
TRUE) {
dir.create(paste(working.dir, "Diagnostic Plots", sep="/"))
}

## checks to see if directory exists, and if not, creates one
for (i in (1:(length(file.list)/2))){
pos.file <- read.table(paste(working.dir, file.list[(i*2)-1],
sep="/"), skip=2, header=F)
if (dim(pos.file)[2] > 7 | dim(pos.file)[2] < 7){
pos.file <- read.csv(paste(working.dir, file.list[(i*2)-1],
sep="/"), skip=2, header=F)
}
count.file <- read.table(paste(working.dir, file.list[(i*2)], sep="/"), skip=2)
## checks if data file is tab or coma delimited and
## reads in each count file and corresponding DAT file
if(sum(pos.file[,6]<3)>0){
pos.file[,6][pos.file[,6]>3] <- mean(pos.file[,6][pos.file[,6]<3],
na.rm=T)
}
## replaces range when sledge is " flying" with average range when
## it is on the bottom (these seconds are discarded and counts
## raised to a whole minute already)
if(sum(pos.file[,6]<3)<1){
pos.file[,6] <- rep(0.88, dim(pos.file)[1])
}

## sets an arbitrary range if the rangefinder was not functioning,
## allowing for 4 cm penetration of the sledge into the seabed
lats[i] <- pos.file[13]
lons[i] <- pos.file[14]
## reads start lat and lon (ok to assume 10 min runs are a point)
png(filename =paste(working.dir, "/Diagnostic Plots/",
strsplit(file.list[(2*i)-1], split="\\.")[[1]][1], ".png", sep=""),
width = 480, height = 480, pointsize = 12, bg = "white", res = NA,
restoreConsole = TRUE)
plot(pos.file[,7]/max(pos.file[,7])~pos.file[,2], ylim=c(01),
type="l", xlab= "Time (s)", ylab="", yaxt="n", bty="n",
main=strsplit(file.list[(2*i)-1], split="\\.")[[1]][1])
```

```
for(j in (1:dim(count.file)[1])){
lines(x=c((count.file[j,1]*60)-5, (count.file[j,1]*60)-5),
y=c(0,count.file[j,2]/max(count.file[,2],na.rm=T)), lwd=4, col=4)
lines(x=c((count.file[j,1]*60)+5, (count.file[j,1]*60)+5),
y=c(0,count.file[j,3]/max(count.file[,3], na.rm=T)), lwd=4, col=6)
}
lines(x=pos.file[,2], y=pos.file[,6]/max(pos.file[,6], na.rm=T),
col=2)
lines(x=pos.file[,2], y=pos.file[,5]/max(pos.file[,5], na.rm=T),
col=3)
legend(x=0, y=1, legend=c("Distance", "Range","Depth","Count 1",
"Count 2"), col=c(12 346), lwd=2, cex=0.6)
dev.off()
## produces a folder of diagnostic plots to help track problems
colnames(count.file)<-c("Mins", "C1", "C2")
minutes <- dim(count.file)[1]
distance.covered <- vector(length=minutes)
mean.count <- vector(length=minutes)
view.width <- vector(length=minutes)
average.height <- vector(length=minutes)
if (pos.file[17]<30){
start.dist <- pos.file[17]
}
□

if (pos.file[17]>30){
start.dist <- 0
}
for (x in (1:minutes)){
temp.mat <- pos.file[pos.file[,2]<=count.file[x,1]*60 and
pos.file[,2]>=(count.file[x,1]-1)*60,]
## creates matrix of data which lies in the appropriate minute
distance.covered[x] <- temp.mat[dim(temp.mat)[1],7] - start.dist
average.height[x] <- mean(temp.mat[,6] - height.differential)
## works out distance covered and average height of sledge
view.width[x] <- 2 * (average.height[x]/cos(lower.edge.view*(pi/180)))*tan(0.5*
horizontal.angle*(pi/180))
## calculates view width for that minute
start.dist <- temp.mat[dim(temp.mat)[1],7]
}
area <- view.width * distance.covered
## produces vector of area viewed in each minute of the run
density.1 <- count.file[,2]/area
density.2 <- count.file[,3]/area
average.density <- ((sum(count.file[,2],na.rm=T)+sum(count.file[,3],
na.rm=T))/2)/sum(area, na.rm=T)
## calculates densities
average.densities[i] <- average.density
counter.1.densities[i] <- mean(density.1, na.rm=T)
counter.2.densities[i] <- mean(density.2, na.rm=T)
```

```
}
return.list <- list(lats=lats, lons=lons, average.density=round(average.densities, 2),
count.1=round(counter.1.densities,2), count.2=round(counter.2.densities, 2))
return(return.list)
## rounds up values and returns them as a list
}
##
## call the function as...
# tv.workup ("C:/Work/TV/Noup", "INDEX. TXT") -> noup.dens
# tv.workup ("C:/Work/TV/North Minch", "INDEX. TXT") -> nm.dens
# tv.workup ("C:/Work/TV/South Minch", "INDEX. TXT") -> sm.dens
```

The index file is a text file which contains details of the survey, such as area surveyed and physical parameters of the sledge, as well as a list of the count and data files to read in.

0805S	- Survey code
FL	- Area code (Fladen)
90 108 9223.557.62 43.60	- Camera parameters
72	- No. sites in file
FL05001.dat	- Logged data file 1
FL05001.txt	- Verified count file 1
FL05002.dat	
FL05002.txt	
FL05003.dat	
FL05003.txt	
(Etc.)	

The sledge parameters are, respectively: height of the front of the camera, height of the rear of the camera, height of the rangefinder and length of the camera, all in centimetres, followed by vertical and horizontal fields of view of the camera, in degrees.

The format of the count files is as follows:

11	- No. of lines to read in
0 0	- 2 mystery zeroes (FORTRAN legacy code?)
1 0 0	- Minute 1 Count 1.1 Count 2.1
2 2 2	- Minute 2 Count 1.2 Count 2.2
3 4 4	- Minute 3 Count 1.3 Count 2.3
4 2 1	- (etc.)

The data from the sledge, such as depth, range off the bottom and distance covered are combined with positional data from the ship or from a Garmin GPS unit and fed into a pc, which logs the data to a file, and prints a hard copy for reference in case of data loss.

The data are logged in the following structure:

fl05001	- Site ID Code
04/06/05	- Date
195130, 0, 57.916, -0.502, 117.6, 0.98, 0	
195140, 10, 57.917, -0.502, 117.7, 1.13, 0	
195145, 15, 57.917, -0.502, 117.6, 1.15, 2	
195150, 20, 57.917, -0.502, 117.6, 1.16, 3	
195155, 25, 57.917, -0.502, 117.5, 1.18, 5	
(etc.)	

cumulative time, run time, latitude, longitude, depth, height of rangefinder, distance covered. In event of the failure of the rangefinder or “ 3 in 1” , or when using the drop frame, additional code is used to generate distance from logged position or to simulate range data.

Appendix C. Multi-annual TORs of ICES WGNEPS

2012/2/SSGESST15 The **Study Group on *Nephrops* Surveys** (SGNEPS) will be renamed the **Working Group on *Nephrops* Surveys** (WGNEPS), chaired by Colm Lordan, Ireland, will meet in Barcelona, Spain, 5–8 November 2013 to work on ToRs and generate deliverables as listed in the Table below. WGNEPS will report on the activities of 2013 (the first year) by 6 December 2013 to SSGESST.

ToR descriptors

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 surveys.	To ensure surveys used by WKNEPH, WGCSE, WGNSSK are fit for purpose.		Recurrent annual update	Survey summary including and description of alterations to the plan, to relevant assessment-WGs (WKNEPH, WGCSE, WGNSSK,) and SCICOM. Planning of the upcoming surveys for the survey coordinators and cruise leaders.
b	To ensure common approaches to protocols, quality control quality and assurance of UWTV data and make recommendations in relation to standard operating procedures as necessary.	There is a need for survey protocols to be documented in the Series of ICES Survey Protocols (SISP).		2 years	Manual for *Nephrops* UWTV Surveys
c	To draft methods paper on the use of *Nephrops* UWTV surveys for the provision of management advice.	UWTV surveys have become the main basis of management advice for *Nephrops* stocks in ICES. There is a need to formally document the approach.		Year 1	Paper in primary literature or ICES CRR
d	To review the WGISUR reports and discuss the utility of *Nephrops* UWTV surveys as platforms for the collection of data for OSPAR and MFSD indicators.	*Nephrops* UWTV surveys have a role in relation to benthic habitat monitoring and the collection of other environmental and ecosystem variables.		Year 3	To update the SISP based on conclusions
e	To review video enhancement, video mosaicking, automatic burrow detection and other	WGNEPS should periodically review emerging technologies that might improve survey method-		Year 3	Technical paper on new technologies and update SISP as appropriate

TOR	DESCRIPTION	BACKGROUND	SCIENCE PLAN TOPICS ADDRESSED	DURATION	EXPECTED DELIVERABLES
	new technological developments	ologies			
g	To review the design, coverage, results and uses of *Nephrops* trawl surveys in consultation with WGISDAA	There are trawl surveys for *Nephrops* in some area and trawling activity also takes place with UWTV surveys. These activities need review and co-ordination.		Recurrent annual update	Survey summary including and description of alterations to the plan, to relevant assessment-WGs (WKNEPH, WGCSE, WGNSSK, WGHMM,) and SCICOM. Planning of the upcoming surveys for the survey coordinators and cruise leaders.

Summary of the Work Plan

Year 1	The main task will be to draft a CRR or review paper in the use of UWTV surveys as the primary basis of management advice for *Nephrops* stocks. ToR A and G will be also addressed annually and plans for ToR B will be made.
Year 2	ToR B will be the main output, work for ToR D & E will be planned.
Year 3	Work will focus on ToRs D and E as well as reviewing any changes in ToR A.

Supporting information

Priority	*Nephrops* are a valuable species whose stocks are potentially susceptible to local depletion. UWTV 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, collaboration, 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	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	This group will feed into the assessment working groups and subsequently on to ACOM
Linkages to other committees or groups	There is a very close working relationship with all the groups of WKNEPH. It is also very relevant to stock assessment experts groups that used the survey results i.e. WGCSE and WGNSSK Links with WGISUR to address ToR D and WGISDAA to address Tor G.
Linkages to other organizations	None

Appendix D. Report WGNEPS meeting 05/08-11-2013 Barcelona Spain by D. de Haan

In order to make an inventory of possibilities of setting up a Dutch survey on *Nephrops* the annual working group meeting of ICES WGNEPS held in Barcelona, Spain in November 2013 was joined. The Dutch commercial *Nephrops* fisheries are mainly in the areas Botney Gut (FU5) and Horns Reef (FU33). There are several options for this survey, such as collaborating with other partners and/or the Dutch fishing industry or setting up an independent survey using own equipment. To make a balanced choice the survey methodology and analysis techniques are to be reviewed as well with the labour associated to these tasks.

European surveys on *Nephrops* are mainly based on underwater video observations to identify and counting burrows of *Nephrops* and using assumption of their occupancy to estimate a total count per area. The subsea equipment consists of a sledge towed on the seabed with single or a twin set of video underwater equipment, underwater lightning and lasers to illuminate a known width of observed field, and an altimeter to record the observed depth relative to the seabed. Data are multiplexed and sent to a deck observation unit using an umbilical with a length depending on the maximum depth range of the survey locations. Video analysis and the identification of burrows take a significant part of the labour requirements. In most cases a crew consists of at least 4 staff members for on-board analysis and the survey is conducted on a 24 hours a day schedule. All the analysis is often done within the available ship's time, thus during the survey itself. In particular the present "state of the art" of automated video analysing techniques was one of the challenges to investigate. At present in the Irish Institute CIEM, Galway develops a software tool to identify burrows in cooperation with a PhD scientist of the Trinity College in Dublin. The technique involves enhancement of the video footage and filtering the burrow entrances and combing them to a mosaic. The presentation of the first results is promising even when electric noise was added to the footage.

Options for a Dutch *Nephrops* survey

The easiest step forward is to collaborate during the Danish IBTS fishing survey, which is targeting an area close by the Dutch *Nephrops* stations on the Horns Reef area (FU33), as supplementary.

Another option is to collaborate with other institutes, such as CEFAS in Lowestoft UK and Marine Science Scotland, in Aberdeen UK. This would reduce operational costs and enable sharing the burrow count analysis, and also create the possibility of training future Dutch analysts. Both survey areas of interest are in the central North Sea and conditional risks related to sea state (with waves larger than 2 m height) are relatively high. The lower outcome of the CEFAS surveys between 2010 and 2013 are indicative for this. However, a part of this is also related to the planning of the UK research vessels (RV "Scotia", RV "Endeavour" & RV "Corystes") with an almost 100% time allocation over the year.

The annual programme of RV "Tridens" covers only 50 % of the time, so the option of using this vessel would have a higher flexibility and a lower risk of not being able to execute the survey, provided surveys during 24 hours a day are possible.

Effects of pulse fishing

A concern was raised about the possible effects of pulse fishing on *Nephrops* as this species do not migrate and their habitat is therefore stationary. Recommendations were made to the ICES SGELECTRA to investigate the impact of pulse fishing on *Nephrops*. The applied underwater observation technique using a sledge can easily be used to position an electrode system on a burrow in the seabed and to observe electric exposures under realistic conditions. The second advantage of this method for *Nephrops* assessment is that it will give an insight in the occupancy rate of burrows, a problem that is criticised as a weak point in the methodology of the assessment of *Nephrops* by using UWTV. A second phase of such a new pulse effect study could be a laboratory experiment together with CSIS, Barcelona. This institute carries out biological behaviour studies on *Nephrops* in an aquarium, which can be used to observe the impact of pulse stimuli to the sensory system as well as the behavioural aspects of the exposure.

Appendix E. *Nephrops* survival

The survival rate of discarded trawl caught *Nephrops* is highly variable and depends on many factors including tow duration, catch composition, air temperature and post capture handling. A value of 25 % is used for *Nephrops* in VIa and IIIa based on studies conducted off the Scottish coast (Sangster et al., 1997; Wileman et al., 1999) which give values in the range of 20-40 %. In the southern part of IIIa the surface water salinity may be as low as 15 psu, which may cause additional discard mortality (Harris and Ulmestrand, 2004).

There are no recent estimates for the fisheries in Area VII but estimates from studies conducted in other areas range from 20 – 40 % in Scottish waters (Wileman et al., 1999) to 45-65 % in the Bay of Biscay (Mehault, et al., 2011). South of Portugal the discard survival was estimated to around 35 % (Castro et. al., 2003). Across most of Area VII discard survival is expected to be relatively low due to lengthy tow durations, volume of catches, prolonged sorting on deck and relatively high density of *Nephrops* on the seabed and a value of 10 % is used in most cases. In FU22 a discard survival of 25% is used based on a study by Morizur, et al (1982). In FU14 discarding is known to occur over non-*Nephrops* habitat and in these cases 0 % survival is assumed.

<u>References</u>

Castro, M., Araujo, A., Monteiro, P., Madeira, A.M., Silvert, W., 2003. The efficacy of releasing caught Nephrops as a management measure. Fisheries Research , 65: 475-484.

Harris, R.R., Ulmestrand, M., 2004. Discarding Norway lobster (Nephrops norvegicus L.) through low salinity layers – mortality and damage seen in simulation experiments. ICES Journal of Marine Science, 61: 127-139.

Méhault, S., Morandeau, F., Fifas, S. 2011. Discarded Nephrops survival after trawling. Working document for ICES Nephrops working group. IFREMER Report of project PRESPO, pp. 15.

Morizur, Y., Charueau A., Rivoalen, J.J., 1982. Survie des rejets de Nephrops norvegicus dans le Golfe de Gascogne et en mer Celtique. ICES CM 1982/B:13 (Note N).

Sangster, G.I., Breen, M., Bova, D.J., Kynoch, R., O'Neill, F.G., Lowry. N., Moth-Poulsen, T. Hansen, U.J., Ulmestrand, M., Valentinsson, D., Hallback, H., Soldal, A.V., and Hoddevik, B. 1997. Nephrops survival after escape and discard from commercial fishing gear. Presented at ICES FTFB Working Group, Hamburg, Germany 14-17 April, 1997, ICES CM 1997 CM/B.

Wileman, D. A., Sangster, G. I., Breen, M., Ulmestrand, M., Soldal, A. V. & Harris, R. R., 1999. Roundfish and Nephrops survival after escape from commercial fishing gear. Final report to European Commission, Brussels, FAIR-CT95-0753.

Appendix F. Recommendations WGNEPS 2013

Training and Reference Material

1. All institutes to produce training and reference material for areas covered by UWTV. As a minimum this is to include annotated 1 minute video footage covering range of density and visibility and other burrowing species encountered and also a photograph guide of signature features of *Nephrops* burrows.
2. A standard operating procedure to be produced for training in *Nephrops* Burrow identification
3. A standard operating procedure to be produced for burrow counting. This is to include details of how many minutes are to be counted, warm-up session details, where to count on the screen and removal of minute counts where footage quality deteriorates.
4. Staff and protocol exchange between institutes where possible and especially on collaborative surveys such as FU15, FU14 and other FUs??
5. Warm up count first minute blind of every station, if a counter resumes counting after a break of more than 8 hours then counter needs to blind count a full station of 10 minutes.

Reference Footage Sets

1. Each institute to produce reference set to comprise of 10 runs of 5 minutes where the footage selected for these reference counts covers the range of visibility, *Nephrops* density and species complexes likely to be encountered in each area. Each institute collated video footage from their archives and burnt them onto DVD with each run comprising a separate chapter.
2. Generate Reference counts how??international, national, exchange, in situ.
3. If reference footage set outdated need to produce new set
4. How many reference sets per area if there is a possibility that they can be learned?

Quality Control of Survey Counts.

1. Datasheets separate for recording counts.
2. First counter records all ancillary information.
3. Institutes to use Linns CCC on station basis to check counter consistency. However, what threshold to use CEFAS and MSS currently use different thresholds.
4. Edge station of low density in sandy ground record 7 minutes and count 7 minutes.
5. Rocky ground record footage if possible for 1 minute and note as zero station.

Quality Control of Navigation Counts.

1. When navigation data for both sled and ship track is collected that institute check the ????

Appendix G. Report CEFAS Nephrops UWTV survey 2011 by Ana Leocadio (SIC), 25/11/2011

CENTRE FOR ENVIRONMENT, FISHERIES & AQUACULTURE SCIENCELOWESTOFT LABORATORY, LOWESTOFT, SUFFOLK, ENGLAND

Report

Survey CEND 16/11
North Sea (FU5 and FU6)

A.M. LEOCADIO (SIC)

J.M. ELSON

A.R. LAWLER

D. EATON

K.R. VANSTAEN

R. MCINTYRE

R. MASEFIELD

M. WHYBROW

D. SIVYER

10/10/2011 08:00 BST – 21/10/2011 17:00 BST

INTRODUCTION

The Norway lobster (*Nephrops norvegicus*) is common throughout the North Sea being a very important fishery for the UK. The present survey focuses two areas of the North Sea, the Farn Deeps (FU6) in the NE coast of England and the Botney Gut / Silver Pit (FU5), an offshore ground shared by the UK and Dutch national waters (Figure 1). Total landings in 2010 for these areas reported 2886 tonnes and 960 tonnes, respectively.
Currently the assessment on *Nephrops* stocks, in the North Sea, is based on underwater television surveys (UWTV) which provides a fishery independent estimate of stock size, exploitation status and catch advice. The *Nephrops* stock assessments are run annually and accordingly on advice from ICES the EC sets annual TACs for this species.

CEFAS has performed annual UWTV surveys since 1996 in the Farn Deeps while just in autumn 2010, for the first time, a TV *Nephrops* survey was undertaken at Botney Gut Silver Pit grounds (Table 1).

Table 13 – Time series of UWTV surveys in the Farn Deeps and Botney Gut / Silver Pit grounds carried out by CEFAS.

Year	Season	Ship	Cruise	UnitName
1996	Spring	Corystes	06/96R	Farn Deeps
1997	Spring	Corystes	5a/97	Farn Deeps
1997	Autumn	Corystes	11a/97	Farn Deeps
1998	Spring	Corystes	5b/98	Farn Deeps
1998	Autumn	Corystes	10/98	Farn Deeps
1999	Spring	Corystes	03/99	Farn Deeps
2000	Spring	Cirolana	1b/00	Farn Deeps
2001	Autumn	Cirolana	07/01	Farn Deeps
2002	Spring	Corystes	1x/02	Farn Deeps
2002	Autumn	Corystes	13x/02	Farn Deeps
2003	Autumn	Cefas Endeavour	09/03	Farn Deeps
2004	Autumn	Cefas Endeavour	13/04	Farn Deeps
2005	Autumn	Cefas Endeavour	15/05	Farn Deeps
2006	Autumn	Cefas Endeavour	16/06	Farn Deeps
2007	Autumn	Cefas Endeavour	18/07	Farn Deeps
2008	Autumn	Cefas Endeavour	17/08	Farn Deeps
2009	Autumn	Cefas Endeavour	14/09	Farn Deeps
2010	Autumn	Cefas Endeavour	15/10	Farn Deeps & Botney Gut
2011	Autumn	Cefas Endeavour	16/11	Farn Deeps & Botney Gut

The specifics objectives of 2011 survey are listed below:

1. To conduct a standard underwater TV survey of *Nephrops* burrow densities on the Farn Deeps grounds, 55^{o} 35’ - 54^{o} 45’ N and 1^{o} 30’ - 0^{o} 40’ W, and to evaluate *Nephrops* abundance (110 stations).
2. To carry out the second year of a preliminary survey of the Botney Gut Silver Pit grounds, 54^{o} 20’ - 53^{o} 40’ N and 1^{o} 20’ - 3^{o} 15’ E, to evaluate *Nephrops* abundance (54 stations).
3. To characterise sediment features at and between TV survey stations using swathe bathymetry.

4. To collect turbidity data
5. To sample *Nephrops* and macro benthos using a 2 m beam trawl deployed at ~ 10 stations in the Botney Gut area.

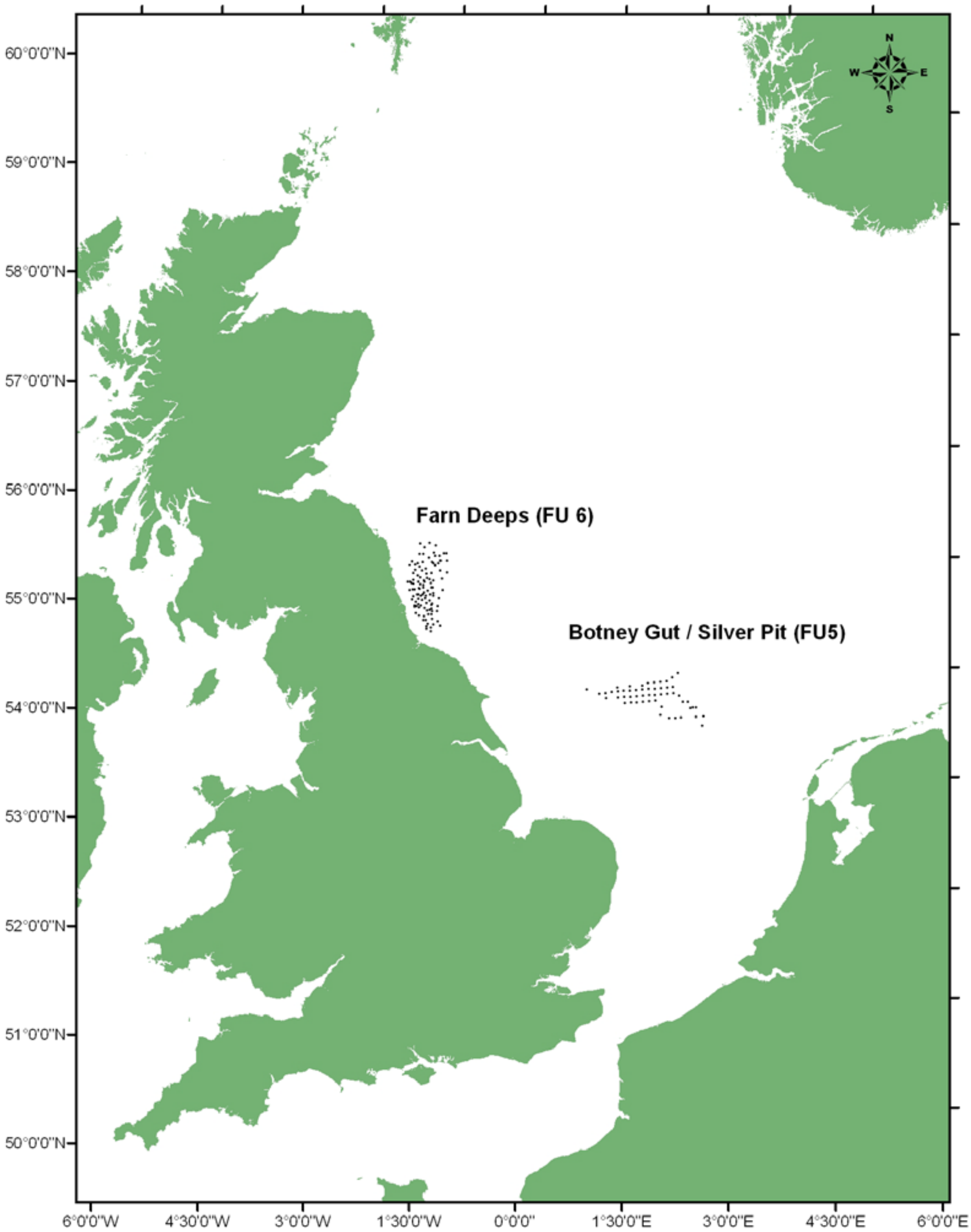

Figure 13 – Map showing the location of both Function Units surveyed.

The first 12 hours were allocated to Dave Sivyer to cover the servicing of a smart buoys (dowsing) and dropping staff ashore (in Hartlepool) on the way up to the Farn Deeps. Time will was coved by Dave's Sivyer project.

MATERIAL AND METHODS

The 2011 North Sea *Nephrops* UWTV survey took place on RV Endeavour between 10^{th} to 21^{st} October. The departure and arrival port was Lowestoft.

Survey design

For the Farn Deeps the survey design is based on a randomised fixed grid and includes a total of 110 stations. The survey design for the main area of the Botney Gut / Silver Pit grounds is also based on a randomised fixed grid with approximate 3 nautical miles distance in-between stations. The initial ground perimeter has been delimited by the combination of VMS data and BGS sediment maps. Based on last year survey results for the Botney Gut area another 15 new stations were added to ensure a better definition of the *Nephrops* ground limits, especially in the Dutch national waters which was not covered in 2010.

At each station a sledge mounted TV camera was deployed and a clear 10 minute tow was recorded onto DVD and DVT. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 1 to 2 seconds.

The sledge was equipped with:

- a camera at an oblique angle to the sea bed, sighted towards the front of the sled;
- 4 LED lights to fully illuminate the field of view;
- 2 fan lasers to delimit the field of view (standard field of view 81.5 cm, reduced to 65 cm due to the use of the camera and the sinking of the sledge);
- a transponder so that the sledge can be retrieved if lost;
- a turbidity meter.

The Dynamic Positioning system (DP) was used throughout the survey to provide a controlled towing speed of around 0.7 knot.
Swathe data were collected on the survey between and over TV stations.

Recounts

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and validated using reference footage (measured by Linn's concordance correlation coefficient (CCC)) prior to recounting 2011 footage. A limit of 0.5 was used to identify counters who need further training. After this process complete, all CEND 16/11 recounts were conducted, as blind counts, by two persons during the survey. Here, the number of *Nephrops* burrow systems and the activity in and out of the burrows were counted by each minute block (for 7 clear minutes). In case the field of view became obscured by cloud the seconds obscured were recorded and all minute blocks with more than 20 minutes obscured were rejected. After all counts completed again the Linn's CCC was applied to check which stations needed to be revisited and were a 3rd or 4th counter needed to be added.

Parallel the burrow counts, during the review process of the videos, also the visibility, ground type, trawl marks, occurrence of bio-fauna, ground contact of the sledge, cloud and any other interference was recorded during one-minute intervals too, using a classification key.

For posterior analysis, counts of burrow systems are converted into densities at each station using the width of view and the length of the tow. Each system is assumed to represent one adult *Nephrops* and occupancy is assumed to be 100%. Overall abundance is estimated by raising the mean density to the appropriate strata area. Total survey abundance, variance and confidence limits are then calculated. To estimate the spatial structure of *Nephrops* densities a geo-statistical analysis is carried out.

Beam trawl

A wooden frame two beam meter trawl was conducted across the Botney Gut / Silver Pit ground, in areas where last year survey identified high density of small burrows. The tows intended just to be qualitative with the aim of identifying the macro fauna associated with this small burrow grounds and also to identify the length frequency distribution of *Nephrops* living in these areas. A total of 7 stations were towed at 1 knot during 10 minutes, to cover at least the same area that was previously TV surveyed. All *Nephrops* caught were sorted by sex and measured to the lowest millimetre carapace length, total weight (g) was also recorded. The benthic catch was sorted by species and sampled by weight (g) and number.

Health and Safety

As required all staff had a valid ENG1 health certificate and a Personal Sea Survival Certificate.
Also the following risk assessments were acknowledged:

G01 – Working in offices, laboratories (NOT including the use of microscopes or special equipment) and in all non-specialised areas on CEFAS property;
G02 – Travelling while on official duty in Official or private vehicles, including loading and unloading equipment, baggage, etc., but excluding the carriage of dangerous chemicals, the use of HGV or specialised vehicles;
G03 – Participation in research cruises on CEFAS owned and managed ships. The collection of samples and data all subsequent processing whilst on-board, including the use of the ships sea-rider.
FD-CF-SHELL-RA-09-MB001 – *Nephrops* TV cruise activities

No COSHH required for the present survey.

RESULTS and FINAL CONSIDERATIONS

Technical aspects

Due to a failure of the “Simrad” camera usually used for this survey a HD camera was used instead. Had to reduce field of view from 81.5 cm to 65 cm, which is the maximum field of view with this HD camera due to the housing.

The standard overlay generally used in this survey was not available. The alternative overlay used had a 10 second refresh rate (position and times) which is too coarse for this work. Also the other inconvenient of this overlay was it covered too much of the screen and was not able to type all information in.

Both towing cables failed on the 20th October. Although the bad weather was the main cause why we didn't accomplish the stations in the Botney Gut area, the fact of both towing cables didn’t work in the last day unable us to do the minimum stations required for this area (10 stations out of 54 stations).

TV survey

In 2011, 110 stations were surveyed in the Farn Deeps (FU6), from 11 Oct (00:15 GMT) to 17 Oct (08:40 GMT) (Figure 2). Due to trawling activity in some areas, mainly close to shore off North Shields, 28 of these stations were repeated at least once, until a reasonable good visibility was achieved. With the exception of one station all others were successfully completed.

A total of 5 CTD dips were carried out to calibrate the multi-beam.

In this year survey, beside the several attempts on covering the Botney Gut / Silver Pit grid, poor weather and technical problems did not allow the TV stations to be surveyed. The time spent in the Botney Gut / Silver Pit area was from 17 Oct (20:34 GMT) to 21 Oct (02:30 GMT).

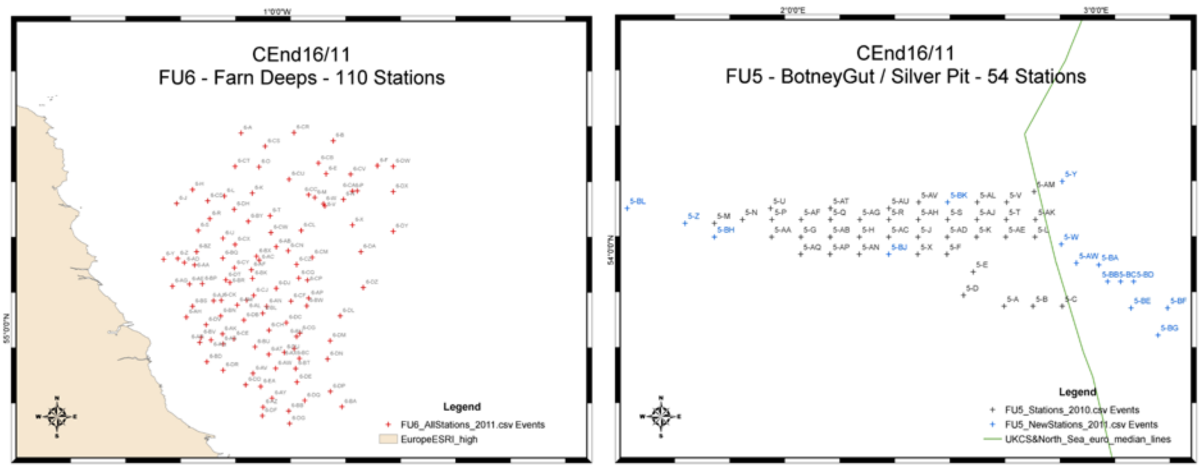

Figure 2 – Map showing the location of both fixed grids for the Farn Deeps and Botney Gut (green line represents the border between the UK and Dutch national waters; blue stations stand for the new stations added in 2011).

Nephrops burrow live-counts were made over a 10-minute tow, which was recorded on DVD and DV tape. All recordings were then recounted under controlled conditions; burrows were counted by each minute block for 7 clear minutes. The counting performance of the 2011 counters was generally very high with Linn's CCC scores >0.7 for most of the stations. A map of the observed burrow counts for 2011 on the Farn Deeps is showed in Figure 3.

Preliminary results suggest that stations close to shore tend to show higher counts than those in the eastern side of the ground, similar to last year results. Burrow counts are typically lower close to the ground boundary which implies a well-defined boundary.

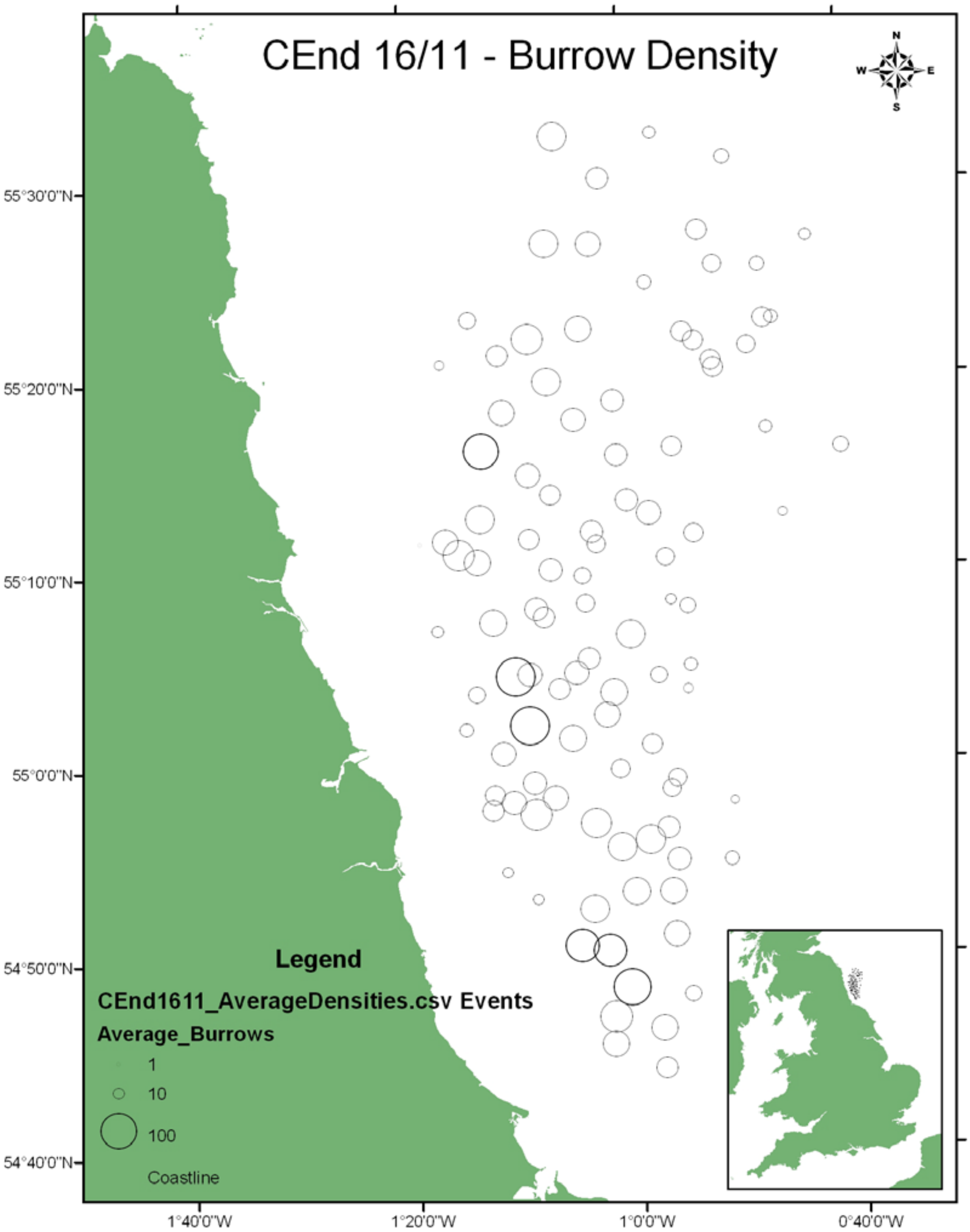

Figure 3 – CEND 16/11 bubble plot of the relative burrow counts from standard TV tows on the Farn Deeps ground.

The preliminary geo-statistical analysis is plotted in Figure 4. The 2011 final abundance estimate of 794 million burrows is lower to that estimated in 2010; the abundance did decline by 11% from 2010 to 2011.

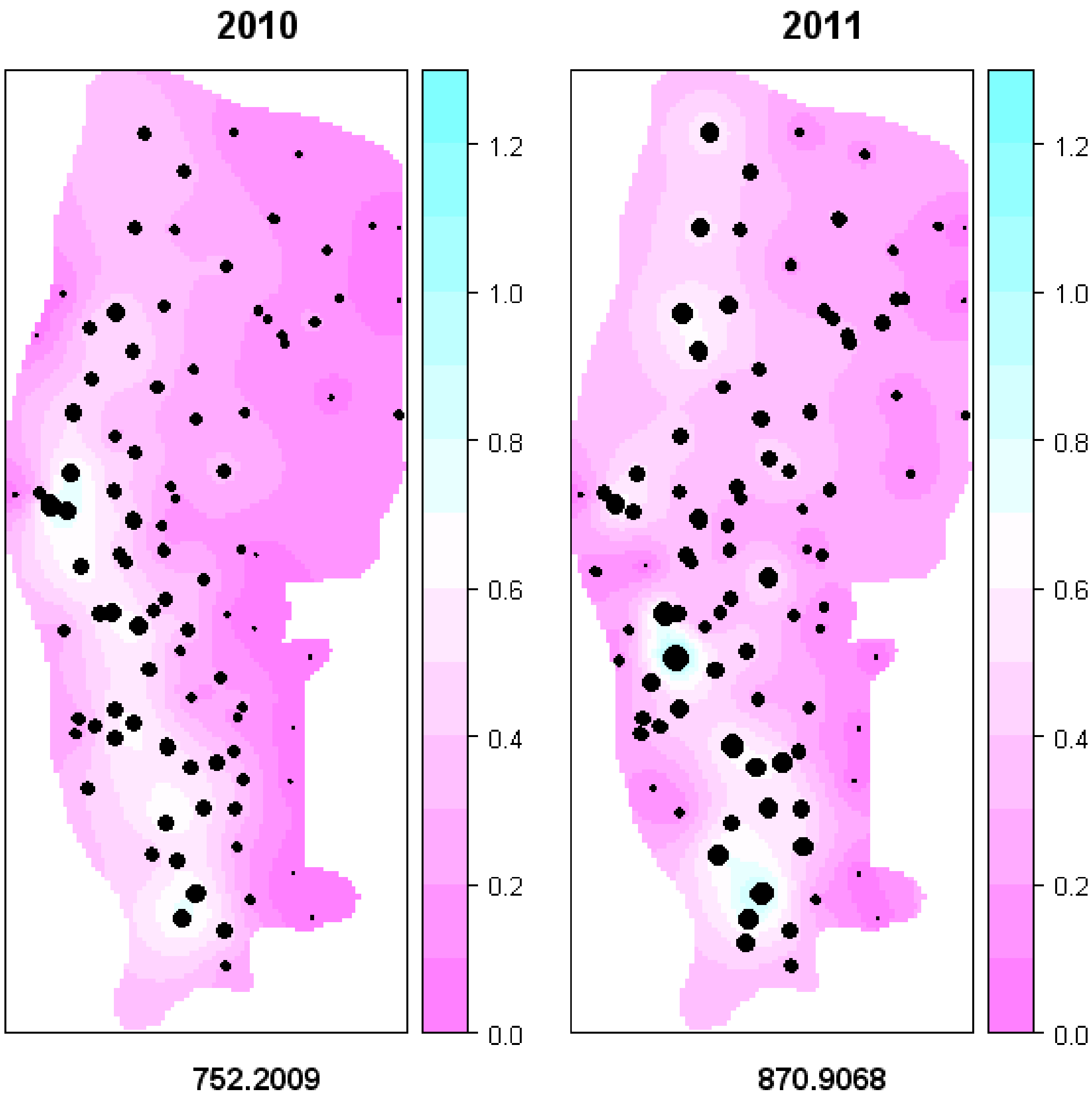

Figure 4 – Geo-statistical abundance estimates (in millions of burrows) for the Farn Deeps (FU6) from 2010 - 2011.

Trawl marks were noted at 43.6% of the stations surveyed. The survey timing ran into the start of the fishing season and this activity disturbed our work, mainly close to shore off North Shields. It is important to highlight the occurrence of trawl marks on the footage; it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult; only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops*.

Beam trawling – Botney Gut / Silver Pit (FU5)

In 2010, were identified patches (eastern side of the grounds) of high abundance of very small burrows systems presenting *Nephrops* signatures (Figure 5). Burrow identification in the Botney Gut / Silver Pit was notoriously difficult due to the high burrow densities of small burrows and sometimes poor visibility (soft mud). Thus, this year an important objective of beam trawling these areas was to identify the size distribution of *Nephrops* and also identify other burrowing organisms.
Conversations with fishermen suggest a high abundance of small *Nephrops* in this part of the ground although the occurrence of other burrowing organisms can also lead to misidentification of the burrow systems. Accurate identification of *Nephrops* burrows gets more difficult on small burrow sizes were the signatures are harder to recognise.
This data should help us on the identification of small burrow systems.

A total of 11 tows were made along 7 different stations. The catchability of the wooden frame 2 m beam trawl was not very good, as it was a very light gear in a very soft muddy bottom. When weight (chains) was added the gear just sank into the bottom and didn't perform very well either. For further beam trawling in this area is highly recommended trying a different type of beam trawl, probably a 3 m Jennings type.
In the few successful tows made it was verified a high number of small *Nephrops*. The *Nephrops* size ranges from 9 mm CL to 32 mm CL, being 63% below 24 mm CL (MLS). The main associated burrowing species was *Goneplax rhomboids*. Further beam trawling need to be done before taking final conclusions, although the presence of high number of small *Nephrops* might explain the presence of many complexes of small burrow systems.

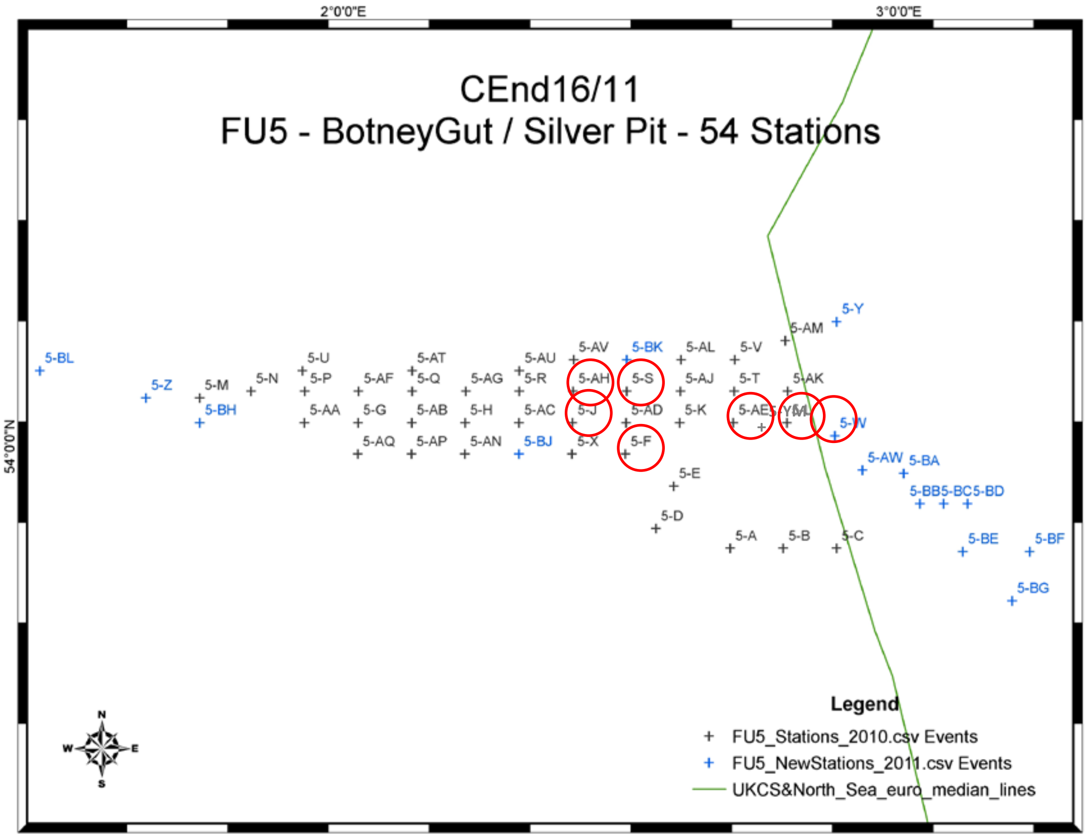

Figure 5 – Beam trawl stations completed in the Botney Gut / Silver Pit area, in 2011.

The main objectives of the survey were successfully met for this year in the Farn Deeps. The UWTV coverage was excellent (100% stations done) and the overall footage quality was good in the Farn Deeps grounds due to favourable weather conditions and minimal technical difficulties. Although the survey timing ran into the start of the fishing season making the recording of good footage in the more western stations more difficult. One way of going around the problem was covering these stations overnight.

In this year survey, beside the several attempts on covering the Botney Gut / Silver Pit grid, poor weather and technical problems did not allow the TV stations to be surveyed. Results from the beam trawl survey revealed a high density of small *Nephrops*. Although, new gear types should be tested to get better catchability and thus improve the description of the size component of *Nephrops* and the identification of other burrowing species. An additional survey will take place in April 2012 to cover again this area.

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We would like to express our thanks and gratitude to the Captain and crew of RV Endeavour for their good will and professionalism during the survey. Also thanks to P&O Maritime for handling all gear and sort any technical difficulties. Finally, thanks to all CEFAS staffs on-board for their hard work and enthusiasm in making this survey a success.

Appendix H. Survey based assessments

It has long been recognized that the standard assessment-prediction procedure used for finfish is not readily applicable to *Nephrops*, therefore the methods for providing advice for *Nephrops* have evolved over several years.

In 2009, WKNEPH debated the use of UWTV surveys as either an absolute measure of abundance or a relative index (ICES, 2009). WKNEPH2009 considered that using the surveys as relative indices would not provide a sufficient assessment of the stock without consideration of other information on stock dynamics. The key concerns about using an index of abundance as the sole piece of information for an assessment were the inability to determine an appropriate level of harvest using explicitly derived harvest rates, to determine appropriate reference points, to understand the relationship between changes in indices and changes in harvest rate and to understand other key aspects of *Nephrops* population dynamics such as recruitment. Any harvest control rule that used an index alone would have to be able to determine a TAC in the absence of an explicit application of a harvest rate to stock size.

Taking all these issues into consideration, the workshop concluded that using the surveys as relative indices did not take all available information into account and was unlikely to provide sufficient precaution at this time.

This led to a consensus that bias corrected survey abundance estimates could be used directly in the formulation of catch advice. The approach that has emerged from WKNEPH2009 is to use UWTV-surveys to provide an absolute estimate of abundance from which recommended catch and landings are derived according to an accepted harvest rate (HR - catch/biomass). The recommended values for the HR are obtained from length-based yield and biomass per recruit analysis.

However, WKNEPH2009 considered that use of the UWTV surveys as absolute estimates of biomass, without explicit consideration of the bias associated with the surveys, would not be a sufficient approach. Experience with other fisheries (*e.g.* NEA mackerel, see MHSAWG 2005) has demonstrated that while biases in survey results may sometimes balance themselves out, the assumption of continuing balance is risky and ill-advised.

Taking explicit note of the likely biases in the surveys may at least provide an estimate of absolute abundance that was more accurate but no more precise. WKNEPH2009 analysed key bias contributions for each of the FUs investigated by UWTV surveys. Overall these suggest that in order to be used as absolute estimates of biomass within an assessment the survey data should be adjusted, on an individual FU basis.

A similar correction is required to harvest rates. As an example, harvest rates in the North Minch, South Minch and Clyde, calculated for 2006 and 2007 when catches are anticipated to be more accurately reported (after the implementation of the buyers and sellers scheme) have been at or above

20% in these two years, are coincident with a reduction in the UWTV survey estimate. Although a causal link between the increase in catch limit in these FUs and the reduction in UWTV survey estimate is not proven, these coincident events provide at least some evidence these harvest rates are too high for these FUs. On the other hand, the Firth of Forth abundances appear to remain stable at harvest rates greater than 20%. FU6 has experienced a lower harvest rate and the UWTV survey index has declined to the lowest observed level commensurate with a decline in the fishery. Other FUs, with harvest rates below 20%, appear to have stable UWTV survey trends. Therefore, in a similar way to the bias correction for the UWTV survey estimates, harvest rates should be applied individually to FUs.

An UWTV survey counts the number of burrows along transects. This leads to an estimate of density of burrows (numbers of burrows per m2) in the investigated area. There are several designs of such surveys with different statistical properties, as described in ICES SGNEPS2012.

The density is applied to an estimate of the total fishable area. Various methods have been used to estimate the area of the fishing grounds and define the boundaries. In many cases VMS data have been used either using manual interpolation of boundaries or using algorithms such as convex hull to objectively define the boundary. However, using VMS data to estimate the area can be sensitive to the spatial and temporal resolution of data, especially where the spatial extent of fisheries varies between years. Where there is such variability occurs the union of defined polygons over a number of years is probably preferable to taking an average over the years. An alternative approach using nested grids to define the spatial extent and frequency of trawling impact at and appropriate spatial scale could also be applied in future (Gerritsen et al., 2013).

There is a lower limit to the size of *Nephrops* burrows that can be identified during UWTV surveys. Very small *Nephrops* are thought to be associated with the burrows complexes of adults (Marrs et al., 1996). The size at which *Nephrops* construct burrows of their own is not certain. There are also technological limitations on the smallest burrow entrance that could be observed. The consensus at WKNEPH 2009 (ICES, 2009) was that survey selectivity had an L50 of 17 mm (knife-edge selection with a likely detection range of 15–20 mm). There was no new information available at WKNEPH 2013 to revise this estimate. Thus the burrow densities and abundance estimates in numbers from UWTV surveys are for individuals >17 mm in the exploited area.

As an example, in 2012 Marine Institute conducted the first underwater television survey (UWTV) on the Porcupine Bank. The survey was based on a randomized fixed isometric grid design (Lordan et al., 2012). The methods used during the survey were similar to those employed for UWTV surveys of *Nephrops* stocks documented by WKNEPHTV (ICES, 2007) and SGNEPS (ICES, 2009; 2010).

In order to use the survey abundance estimate as an absolute it is necessary to correct for potential biases. For the Porcupine Bank the field of view of the camera was 0.75 m and expert judgment of the mean burrow diameter was in the range of 0.55–0.65 m. The estimated edge effect bias was in the range of 1.24–1.28 using the simulation approach suggested by Campbell et al. (2009). This seems low compared with other areas but it is based on the best judgement of burrow diameter from the foot-age. In future it may become possible to quantitatively estimate burrow diameter from mosaics of the footage from this and other areas. Burrow detection rates were thought to be relatively high due to good water clarity and few other burrow systems of similar size. Burrow identification could be slightly overestimated since a few fish and squat lobsters were observed at burrow entrances. The proposed cumulative correction factor for the area was 1.26. When compared to with the correction factors applied in other areas it is quite close to the average used on other grounds.