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GULF OF CADIZ *Nephrops* Grounds (FU 30) ISUNEPCA 2017 UWTV Survey and catch options for 2018

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NTRODUCTION

The Norway lobster, *Nephrops norvegicus,* is one of the main commercial crustaceans exploited by a unique and highly multispecific bottom trawl fleet in the Gulf of Cadiz (Jiménez et al, 2004; Silva et al., 2007). Despite annual catches of *Nephrops* are small compared with other Atlantic *Nephrops* stocks (>100 t annually 2017 and 2018), this species gives valuable revenues for the trawl fleet. In the Gulf of Cádiz, *Nephrops* occurs in sandy-muddy bottoms from 200 m to 700 m depth (Sobrino, 1994), where sediment is suitable for them to construct their burrows. It is well documented that this decapod spends a large part of the time in their burrows and their emergence behavior is influenced by several factors such as time of the year, light intensity, sex, size or reproductive stage (Froglia and Gramito, 1986; Chapman, 1980; Tuck et al., 2000; Aguzzi and Sardá, 2008).

Underwater television (UWTV) surveys for monitoring the abundance of *Nephrops* populations were pioneered in Scotland in early 90's. The estimation of Norway lobster abundances using UWTV systems involves identification and quantification of burrow density over the known area of *Nephrops* distribution (ICES, 2007). This can be used to produce a raised abundance estimate for the stock. Thus, UWTV surveys and assessment methodologies have been developed for providing a fishery independent estimate of stock size, explotation status and catch advice for several NE Atlantic *Nephrops* stocks. (Campbell et al., 2008; ICES, 2009).

Up to 2016, the ICES advice for the *Nephrops* stock in the Gulf of Cadiz (FU 30) was on the basis of a data-limited approach. According to this approach, FU 30 was considered as category 3.1.4 (ICES, 2012a) and it was assessed mainly by the analysis of the LPUE series trend. This stock was benchmarked in October 2016 (ICES, 2016a). The approach based on UWTV survey to generate catch options was proposed for this FU. WKNEP 2016 mainly considered in detail: the technology of the survey, including correction for edge effects, discovery rate, species identification, etc., the distribution area and coverage and the derivation of a recommended harvest rate (ICES, 2016a).

Regarding the first two points, WKNEP concluded that the UWTV survey based assessment as described before is appropriated for this stock. However, some difficulties were found for the derivation of the reference points. The common length based yield per recruit method was not appropriated for this stock. Reference points were derived from the perception of the stock and historical experience from similar previously assessed stocks as an interim solution. However, ADGNeph 2017 agreed that the poor fits in the length-frequency model, normally used for calculating F_{MSY} for category 1 *Nephrops* stocks, prevented its application to FU 30 (ICES, 2017a). In absence of stock specific MSY harvest rates the basis of the advice for this stock will follow the category 4 approach for *Nephrops* as is recorded in the stock annex.

The Spanish Oceanographic Institute (IEO) carried out the fourth *Nephrops* UWTV survey on the Gulf of Cadiz fishing grounds in 2017, although UWTV survey in 2014 was considerate only exploratory. This survey was multidisciplinary in nature and the specific objectives were:

1. To obtain estimates of *Nephrops* burrows densities

2. To confirm the boundaries of the *Nephrops* area distribution

2. To obtain estimates of macrobenthic species and the occurrence of trawl marks and litter on the seabed

3. To collect oceanographic data using a sledge mounted CTD

This working document details the results of FU 30 UWTV survey in 2017 which were used in the last advice carried out in November 2017.

MATERIAL AND METHODS

The ISUNEPCA TV survey was carried out from 18nd to 31st May 2017 in Spanish waters of the Gulf of Cadiz (FU 30) onboard RV Angeles Alvariño. The UWTV designs followed a randomized isometric grid of stations at 4 nm spacing. A total of 65 stations were planned covering the *Nephrops* area distribution established in the last benchmarck (ICES, 2016a) (Figure 1). Additionally, 3 stations were planned but considered as exploratory. The *Nephrops* ground boundary was established using a combination of VMS and logbook data, *Nephrops* abundance data obtained in the IBTS surveys series carried out in this area and bathymetric information (Vila et al., 2014). The *Nephrops* area corresponds to 3000 Km^2. Some stations were lightly moved to avoid the morphology of the bottom such a deep channel in the southwest part and a submarine pipeline in the shallowest limit. Stations ranged from 90 to 650 m depth. Hauls using a beam trawl were carried out in order to know the presence of other burrowing megafauna which co-occurs with *Nephrops* and could be source of confusion in the identification of *Nephrops* burrows.

The UWTV sledge is equipped with a Full HD camera (angle of 45°) giving a field of view (FOV) of 0.75 m, which is confirmed by two lasers. The protocols used were those reviewed by WKNEPHTV (ICES, 2007) and annually by Expert Group on *Nephrops* surveys (SGNEPS/WGNEPS) (ICES, 2009b, 2010, 2012b). At each station, the sledge was deployed and once stable on the seabed a 10 minute tow was recorded. The sledge was towed at between 0.5-0.7 knots in order to obtain the best possible conditions for counting burrows. Video footage corresponds to 200 m swept, approximately. Vessel position (dGPS) and position of sledge, using a HiPAP, were recorded every 1 to 2 seconds. The distance over ground (DOG) was estimated from the position of sledge in all stations.

According to the SGNEPS recommendations all scientists were trained and familiarized with the identification of *Nephrops* burrows (ICES, 2009b) using training material and validated using FU 30 reference footages prior to recounting at sea. The FU 30 reference footages were create before the UWTV survey following the recommendations done from WKNEPS in 2016 (ICES, 2016b) and according to the WKNEPHBID (ICES, 2008). Three national and one international counter from Marine Institute of Irland were involved in this process. The reference counts for each station were taken as an average per minute of the four counters

Individual's counting performance against the reference counts was measured by Linn's concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. This year, all recounts were conducted by three trained "burrow identifying" scientists independent of each other. Lin's CCC R script was implemented and applied to all recounts to identify those stations which required additional counts. Only stations with a threshold lower than 0.5 were reviewed again by consensus among the three counters. The number of *Nephrops* burrows systems and *Nephrops* in and out of burrows were counted for each one-minute interval according to WKNEPHBID (ICES, 2008). Visibility was subjectively classified using the follow classification key: excellent, good, ok, ok-poor, poor and nil. Ground type and speed of the sledge was also recorded according to the standard classification keys.

Footages were also used for quantification of other megafauna species by a different team of scientists than the "burrow identification" team. The abundance was estimated using a rank-system composed by 6 categories from absent (0 indiv.) to extremely abundant (>100 indiv.). Trawl marks and litter were recorded as presence/absence.

Estimates of density at each station were calculated from standardized *Nephrops* burrows recounts divided by the area observed. This area was calculated multiplying the DOG by the FOV. Then, *Nephrops* burrows density was raised to the total area surveyed. The spatial co-variance and other spatial structuring Geo-statistical analysis were conducted using ARCGIS software. Geostatistic analysis was carried out applying an ordinary kriging. The result of kriging was used to obtain the *Nephrops* burrows abundance estimate, dividing the area in polygons with the some density range and raising this density to the surface of the each polygon. The summary of the method used in the geostatistic analysis is shown in Table 1. Krigged estimation variance or CV was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997).

A number of factors are suspected to contribute as bias to UWTV surveys. In order to use the survey abundance estimate as absolute it is necessary to correct for these potential biases. The main bias is the "edge effect" which is a moderate source of overestimation when deriving *Nephrops population* size from underwater TV surveys. This bias is related to the counting of burrow complexes which lie mainly outside the viewed track. Other bias identifies are the "burrow detection" and "burrow identification regarding to visibility quality and the presence of other burrowing macro benthic species. The cumulative correction factor for the Gulf of Cadiz was 1.28 (Table 2).

At each station, CTD profile was logged for the duration of the tow using an AML Oceanographic Minos-X mounted on the sledge.

RESULTS

All planned UWTV stations were completed. A few stations had to be repeated due to problems with the visibility from recent fishing activities (4 stations) and only 2 stations had to be finally considered as null. In addition, 3 stations were carried out beyond the deepest *Nephrops* limit and considered as exploratory (blue squares in the Figure 1). In this area, there is no fishing activity according to the VMS information available but the IBTS surveys data indicated the presence of *Nephrops*. A total of 27 hauls from beam trawl were carried out in order to validate the video observations and confirm the limits of the *Nephrops* distribution (Figure 2).

Figure 3 shows the *Nephrops* density (adjusted to account for bias factors) for 2017 in this FU. The density ranged between 0 and 0.53 burrows/m^2 and the average burrow density was 0.13 burrows/m^2. The highest densities were observed in the west part of the area. In the shallowest edge the visibility is poor and the *Nephrops* density is low according to the VMS data and IBTS surveys series generating a high uncertainty in the *Nephrops* burrows identification. Additionally, the information obtained from the beam trawl activity indicated absence of *Nephrops* in hauls carried out at depths lower than 200 m. Therefore, the stations located at the edge of the surveyed area were considered as stations with *Nephrops* density of zero in the geostatistic analysis.

Other burrowing species detected in the beam trawl hauls that co-occur with *Nephrops* were mainly *Munida* sp., *Goneplax rhomboides*, *Monodaeus couchii* and *Macropipus tuberculatus* (Figure 4), being the squat lobster burrows the ones that created the highest confusion in the identification and quantification of *Nephrops* burrows.

The final modeled density surfaces in the UWTV surveys time series (2015-2017) are shown as a heat maps and bubble plots in Figure 5. This year the number of stations used in the geostatistic analysis was higher than the previous years. The abundance estimate derived from the krigged burrow surface (and adjusted for the cumulative bias) was 371 million burrows with a CV of 8.7% in 2017 (Table 3). The stock abundance is estimated to have increased more than 50% in 2017. The spatial pattern of burrow density is consistent in last two years.

Megafauna analyses from underwater image footages are still under processing. Table 4 shows some preliminary results in terms of presence of different species during the survey. A total of 58 footages where visibility was good enough to ensure a proper identification of the species were used for this analysis. The species with the highest frequency of occurrence in the footages (more than 50%) were mainly the sea-pen *Kophobelemnon stelliferum* and the sedentary ceriantid *Cerianthus* sp., followed by the sea-pen *Funiculina quadrangularis* (37.9%) and the squat lobster *Munida* sp. (36%). In less proportion (<30%) the crinoid *Leptometra phalangium*, the sea anemone *Actinauge richardii* and the small soft bottom sponge *Thenea muricata* were observed. The burrowing crab *Goneplax rhomboides* was present in 17% of the footages while the sea urchin *Cidaris cidaris* and the sea-pen *Virgularia mirabilis* occurred in 15% of the footages and the serpulid annelid *Filograna implexa* in 13% of them. Species of commercial interest were also detected, being the most frequent ones the deep-water rose shrimp (*Parapenaeus longirostris*) and the flat fish *Citharus linguatula*.

The near-bottom temperature and salinity data collected during the survey are shown in Figure 6.

CATCH OPTIONS FOR 2018

The UWTV abundance data together with data from the fishery (landings in number and mean weight in landings) are used to provide the scientific advice for *Nephrops* FU 30 in 2017. Discards are considered negligible so all catches are assumed to be landed (ICES, 2017b). The ICES framework for Category 4 Norway lobster stocks (ICES, 2012a) was applied for *Nephrops* FU 30. Table 5 shows the basis for the catch options for this stock. Mean weight in the period from 2013 to 2015 was relatively high as result of restrictive quotas in these years (Figure 7a). Therefore, these were not considered representative to be used in the calculation of the catch advice. The 2016 data was used instead.

Poor fits in the length frequency model (CSA, Cohort Separable Analysis) (ICES, 2016a), normally used for the calculating F_{MSY} for category 1 *Nephrops* stocks prevented its application to FU 30. In absence of stock specific MSY harvest rate, the advice was carried out on the basis of ICES precautionary approach (ICES, 2017). Catch options for 2018 are shown in Table 6. Because of the restrictions imposed on the fishery during 2013-2015, the average catch number in 2010-2012 were divided by the average UWTV abundance estimate from 2015-2017. The corresponding harvest rate is 1.16% which is well below the range of maximum sustainable yield (MSY) harvest rate in all other FUs, and so can be considered conservative. Fishing at precautionary approach in 2017 implies catches of 100 t which is very close to the mean landings from 2010-2012 before than the restriction period. Table 7 shows the assessment summary for *Nephrops* FU 30 in 2017.

DISCUSSION

The Spanish Oceanographic Institute (IEO) carried out an exploratory *Nephrops* UWTV survey on the Gulf of Cadiz fishing grounds in 2014 within the framework of a project supported by Fundación Biodiversidad (Spanish Ministry of Agriculture, Food and Environment) and European Fisheries Funds (EFF). Nowadays, IEO carries out yearly UWTV survey in the Gulf of Cadiz (FU 30) since 2015. This survey has been proposed for the Work Plan 2018 for Data Collection in the fisheries and aquaculture for its funding.

The surveyed area and the number of TV stations have increased since the first UWTV surveys in the Gulf of Cadiz (FU 30) that started in 2014 and the *Nephrops* area is better delimited since 2015. Currently, the TV stations cover well the entire distribution of the *Nephrops* ground (Vila et al., 2016). Nevertheless, the shallowest edge of this area should be analyzed in detail for confirming this limit in the *Nephrops* distribution. VMS information does not show significant fishing activity targeting *Nephrops* below 200 m. Nevertheless, the bottom trawl survey series carried out in the Gulf of Cadiz since 1994 indicates small quantities of *Nephrops* at depths between 90 to 120m. Visibility at those depths is very poor and the presence of other species with a burrowing behaviour could generate a high uncertainty in the *Nephrops* burrows identification. Therefore, the stations located at this edge of the surveyed area were considered to have no *Nephrops* in the geostatistic analysis.

Beam trawl was used during the UWTV survey in 2017 for validating the information obtained in the videos and confirming the shallowest *Nephrops* boundary. The hauls carried out below 200 m depth showed the presence of the burrowing crab *Goneplax rhomboides* but no *Nephrops* were detected in them. Unfortunately, few hauls could be done because of the short duration of the survey. WGNEPS recommended that beam trawl activity should be continued in future surveys for validating the video observations and confirming the limits of the *Nephrops* distribution (ICES, 2017b).

The burrow abundance estimates have increased in 2017 regarding the previous year (233 millions burrows in 2016 and 370 millions burrows in 2017). *Nephrops* spatial distribution is consistent in 2016 and 2017 and is in accordance to the VMS and the IBTS survey information.

The approach based on UWTV survey to generate catch options was proposed for this FU in the framework of WKNEPS in October 2016 (ICES, 2016, a). WKNEPS agreed the UWTV survey in FU 30 is appropriated for give scientific advices for this stock. Nevertheless, specific MSY reference points could not be estimated. The large differences found between the abundance estimate derived from SCA model and the abundance estimated from the UWTV lead high harvest rates and as consequences recommends catches much higher than the obtained historically in the fishery. The problems could be amended to a variable extent in numerous ways, but in particular by increasing the natural mortality in the SCA model, which again would have an impact on the reference points and subsequently on the harvest rate to be recommended.

In absence of MSY reference points, the ICES framework for Category 4 Norway lobster stocks (ICES, 2012a) was applied for *Nephrops* FU 30 in last advice in 2017. In the future if stock specific FMSY reference points can be estimated then the stock will meet the requirements for category 1 assessment (ICES, 2017a). In this sense, a workshop on *Nephrops* reference points has been recommended in order to evaluate reference point estimation methods for stocks with recent TV surveys. This workshop will be carried out in January 2019.

UWTV surveys are an excellent platform for collecting additional multidisciplinary information that is highly relevant for several researchers and advisory applications. The monitoring of benthic macro fauna of circalittoral and bathyal sedimentary areas, such as the sea-pen communities with burrowing megafauna that have been included in the OSPAR List (OSPAR, 2010), the analysis of the impact of fishing activity on the bottom, the presence of litter as well as information of environmental variables are very valuable. CTD data collected, over time will augment the knowledge base on habitat and oceanographic regime on the bottom. This information could also be useful in the context of the Marine Strategy Framework Directive (MFSD) as well as on the management of the recently declared Site of Community Importance "Volcanes de fango del golfo de Cádiz".

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Table 1. Geostatistic method summary

Method	Kriging
Type	Ordinary
Variogram	Semivariogram
Number of lags	15
Lag size	0.034989
Nugget	0.007818
Anisotropy	Yes
Range (Major)	0.524835
Range (Minor)	0.175778
Partial sill	0.010165
Direction (angle)	135.87

Table 2. The bias associated with the estimates of *Nephrops* abundance in FU 30.

	Edge efect	**Detection rate**	**Species identification**	**Occupancy**	**Cumulative bias**
FU30: Gulf of Cadiz	1.24	0.90	1.15	1	1.28

Table 3. Results summary table for geostatistical analysis of UWTV surveys in FU30.

Year	Nª stations	Mean density adjusted	Area Surveyed	Domine area	Geoestatistical Abundance estimate adjusted	CV on burrow estimate
		Burrow/m2	Km2	Km2	Millions burrows	
2015	58	0.0905	3000	3000	298	7.60
2016	58	0.0078	3000	3000	233	7.26
2017	62	0.1336	3000	3000	370	8.70

Table 4. Main megabenthic species observed during UWTV survey with indications of their fequency of occurrence (expressed as %)in the footages.

Species	Frequency of occurrence (%)
Kophobelemnon stelliferum	55
Cerianthus sp.	50
Funiculina quadrangularis	38
Munida sp.	36
Parapenaeus longirostris	29
Leptometra phalangium	29
Gadiculus argenteus	28
Actinauge richardii	28
Thenea muricata	24
Plesionika heterocarpus	21
Sabellidae	21
Goneplax rhomboides	17
Cidaris cidaris	16
Virgularia mirabilis	16
Filograna implexa	14
Citharus linguatula	12
Nephrops norvegicus	12
Plesionika sp.	12
Scyliorhinus canicula	10

Table 5. Basis for catch options for 2018 for *Nephrops* FU 30.

Variable	Value	Source	Notes
Stock abundance	371 million individuals	ICES (2017)	UWTV survey 2017
Mean weight in landings	23.20 g	ICES (2017)	Data 2016
Mean weight in discards	-	ICES (2017)	Not relevant
Discard rate	0%	ICES (2017)	Negligible
Discard survival rate	-	ICES (2017)	Not relevant
Dead discard rate	0%	ICES (2017)	Negligible

Table 6. Annual catch options for 2018. All weights are in tonnes

Rationale	Total catch	Wanted catch*	Unwanted catch^ *	Harvest rate
ICES advice basis				
Precautionary approach	100	100	0	1.16 %
Other options				
F_{2016}	197	197	0	2.29%

Table 7. Assessment summary for *Nephrops* FU 30 in 2017.

Year	Landing in number	Total discard in number*	Removals in number	UWTV Abundance estimates	95% conf. intervals	Harvest Rate	Mean weight in landings	Mean weight in discard	Discard rate	Dead discard rate
	millions	millions	millions	millions	millions	%	g	g	%	%
2015	0.8	0	0.8	298	45	0.3	30.8	NA	0	0
2016	5.35	0	5.35	233	34	2.3	23.2	NA	0	0
2017				371	63					

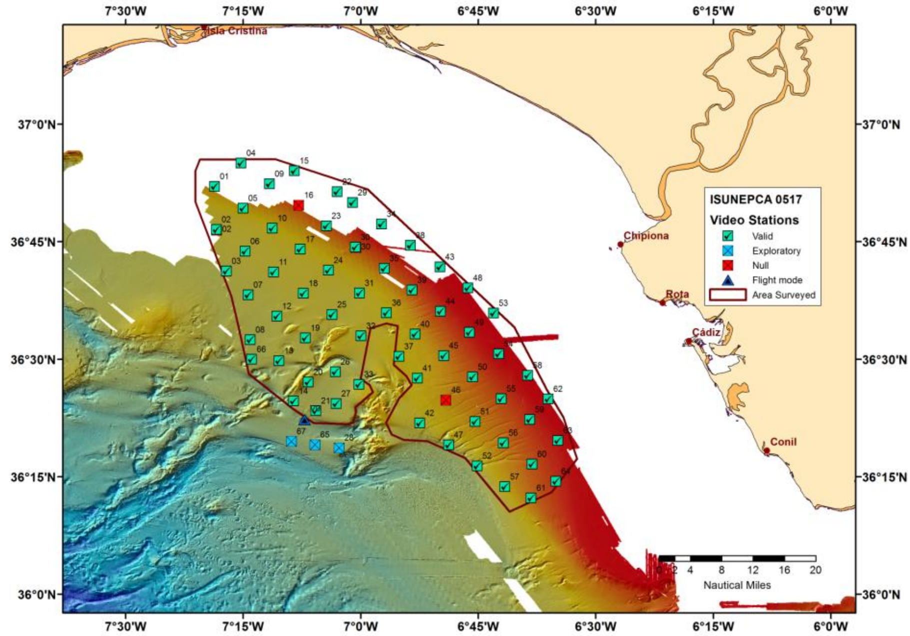

Figure 1. Stations grid planned in UWTV survey in 2017.

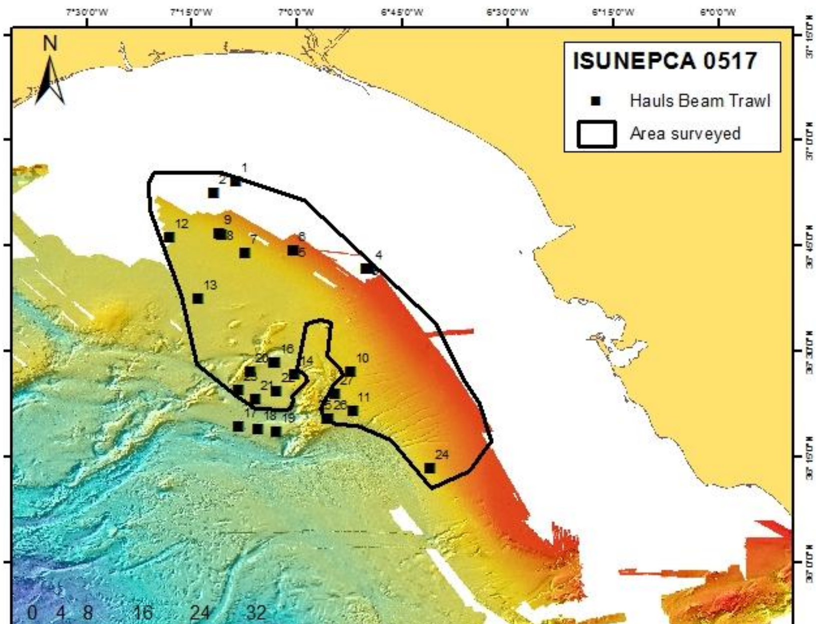

Figure 2. Hauls carried out using beam trawl in UWTV survey in 2017.

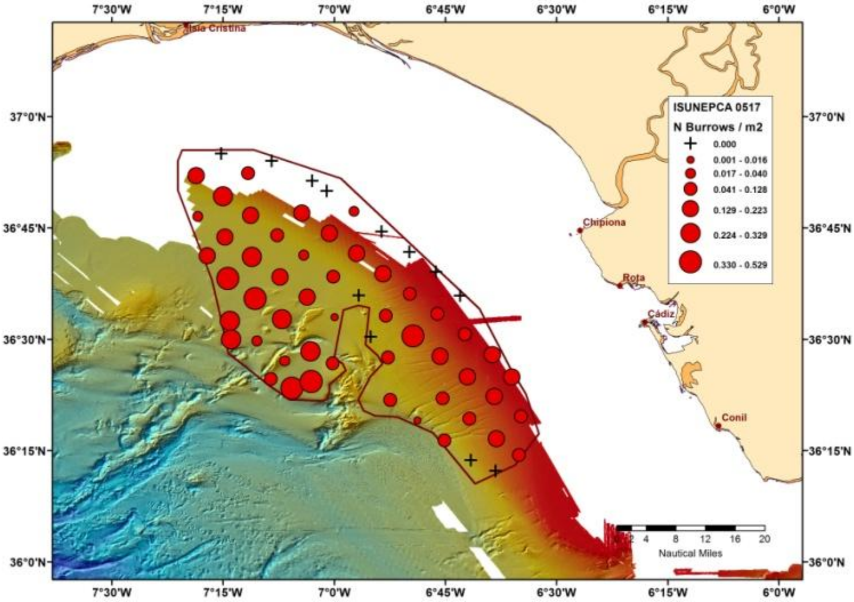

Figure 3. *Nephrops* density adjusted to account for bias factors for 2017 UWTV survey in FU 30. Station positions with zero density are indicated using a +.

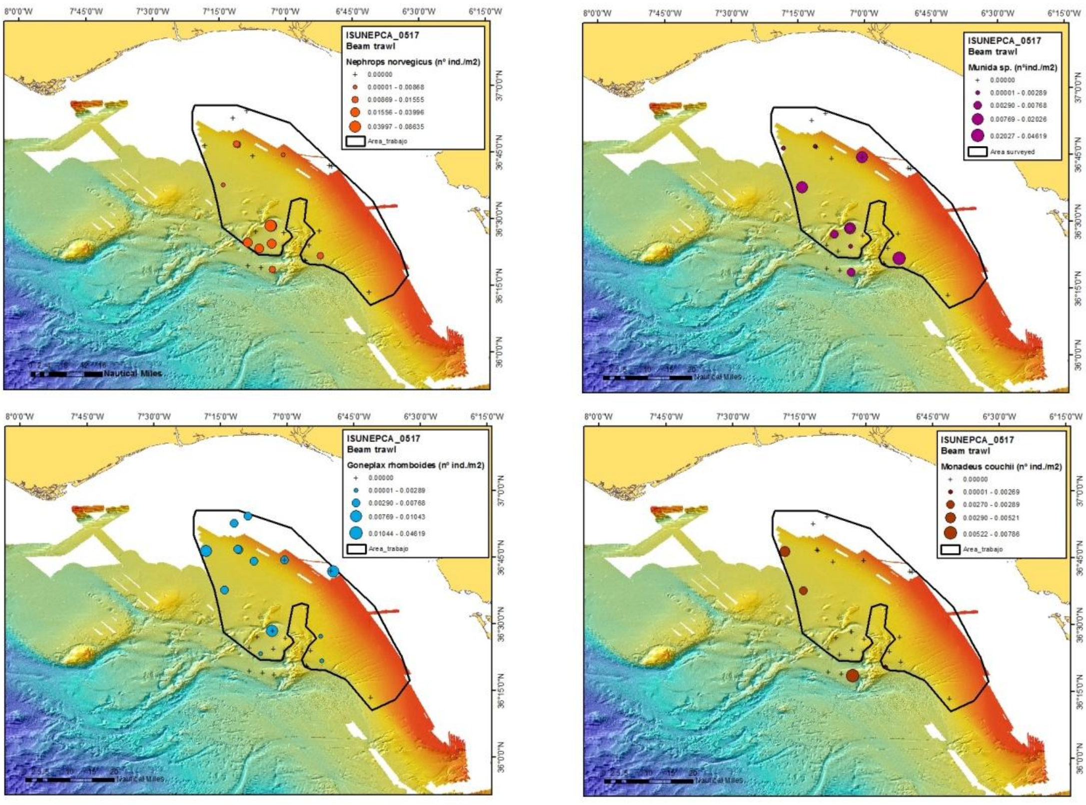

Figure 4. Density of *Nephrops* and other burrowing species obtained from beam trawl

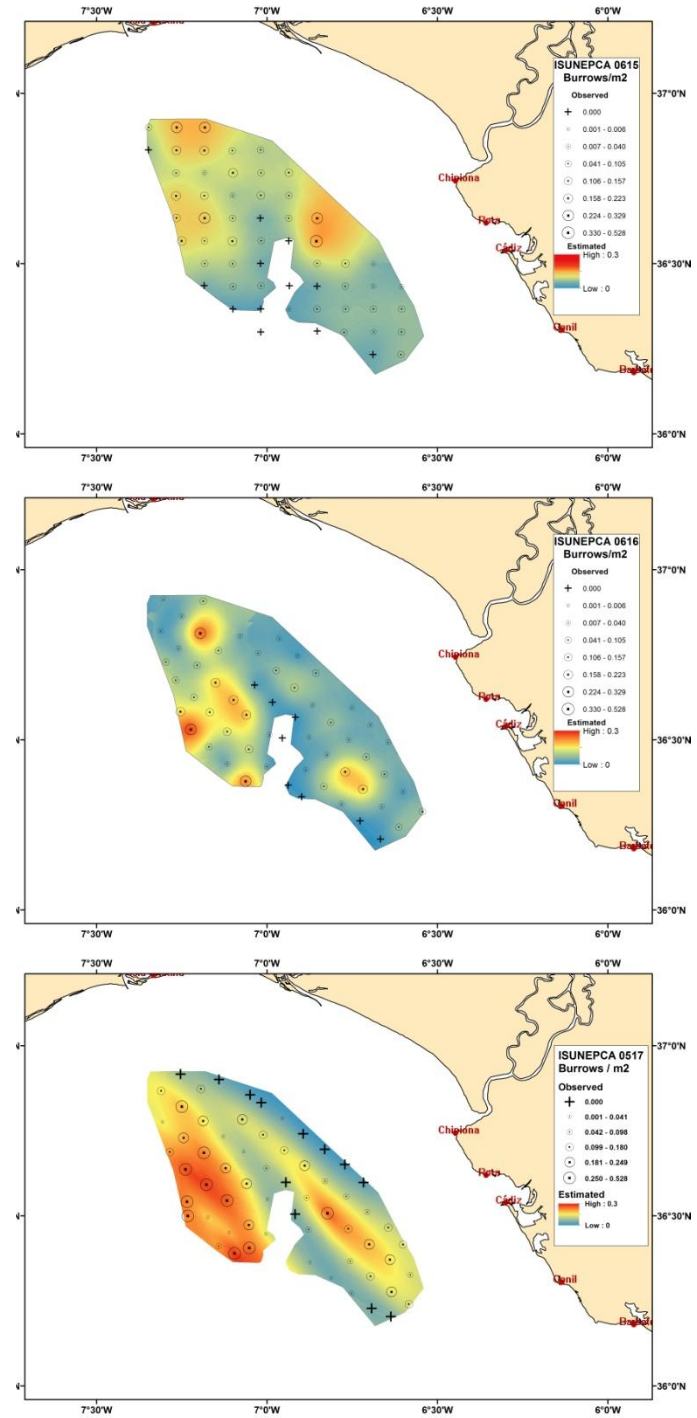

Figure 5. Bubble plot of the burrow density observations overlaid on a head map of the krigged burrow density surface for UWTV survey series (2015-2017). Station positions with zero density are indicated using a +.

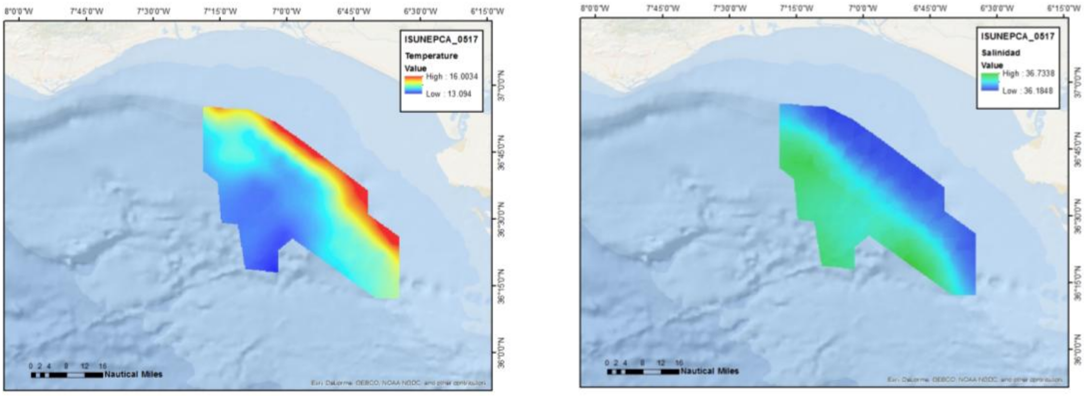

Figure 6. Temperature and salinity on the seabed collected during the survey.

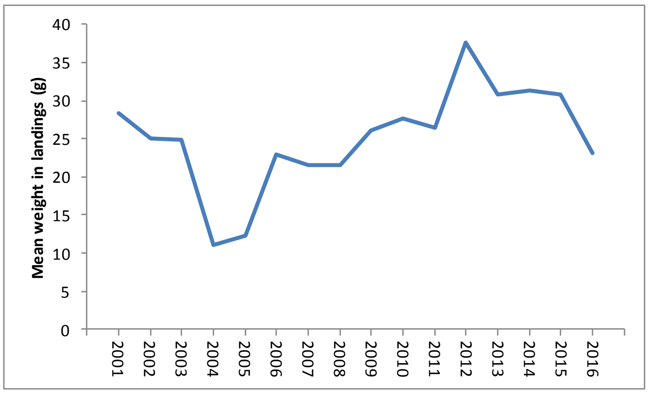

Figure 7. Mean weight in the commercial landings in FU 30.